BEDROCK PRIME: HOW CAN THE UNITED STATES BEST ADDRESS THE NEED TO ACHIEVE DOMINANCE WITHIN THE SUBTERRANEAN DOMAIN?

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Globally, potential adversaries are building ever more complex, stronger, and deeper fortifications which are largely immune to the current United States weapons inventory. Advanced construction and design techniques coupled with technological improvements in mining have created a perfect storm of ultra-strong fortifications located at depths unreachable to all but the most distinctive and matchless weapon systems. A new domain is emerging which must be appreciated for its dynamic effect on policy, strategy and even national resolve. It is not a single adversary but rather a global problem enhanced through information sharing and parallel non-military applications. This issue requires a paradigm shift in the current U.S. strategic and operational approach for countering hostile nations willing to invest in the development of Subterranean Infrastructure and Fortifications (SIF). The U.S. must apply all elements of national power (Diplomatic, Information, Military and Economic [DIME]) and commit itself to develop the capability to hold at risk the deepest targets from a full spectrum of delivery platforms. This will be no small effort. The hardest and deepest buried targets on the planet must be serviceable on an industrial scale. Rock, soil and concrete must be penetrated by sensors and weapons just as darkness and the skies have yielded to modern military technology. Failure in this task will grant our enemies control of a vital and emergent domain.

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

BEDROCK PRIME: HOW CAN THE UNITED STATES BEST ADDRESS THE NEED TO ACHIEVE DOMINANCE WITHIN THE SUBTERRANEAN DOMAIN? By LCDR Michael G. Dudas, USN, 99 pages.

Globally, potential adversaries are building ever more complex, stronger, and deeper fortifications which are largely immune to the current United States weapons inventory. Advanced construction and design techniques coupled with technological improvements in mining have created a perfect storm of ultra-strong fortifications located at depths unreachable to all but the most distinctive and matchless weapon systems. A new domain is emerging which must be appreciated for its dynamic effect on policy, strategy and even national resolve. It is not a single adversary but rather a global problem enhanced through information sharing and parallel non-military applications. This issue requires a paradigm shift in the current U.S. strategic and operational approach for countering hostile nations willing to invest in the development of Subterranean Infrastructure and Fortifications (SIF). The U.S. must apply all elements of national power (Diplomatic, Information, Military and Economic [DIME]) and commit itself to develop the capability to hold at risk the deepest targets from a full spectrum of delivery platforms. This will be no small effort. The hardest and deepest buried targets on the planet must be serviceable on an industrial scale. Rock, soil and concrete must be penetrated by sensors and weapons just as darkness and the skies have yielded to modern military technology. Failure in this task will grant our enemies control of a vital and emergent domain.

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My final words are dedicated to my father, who passed away in 2001. Since before I joined the military, he was always the gentle guiding hand leading to me to where I needed to go as a man, a husband and a father. He taught me honor, sacrifice and strength. He will always be my hero.

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ACRONYMS

CoG	Center of Gravity
DIME	Diplomatic, Information, Military, Economic
DTRA	Defense Threat Reduction Agency
HDBTs	Hardened and Deep Buried Targets
IADS	Integrated Air Defense System
ISR	Intelligence, Surveillance, and Reconnaissance
SIF	Subterranean Infrastructure and Facilities
WMD	Weapons of Mass Destruction

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CHAPTER 1

INTRODUCTION

Bedrock Prime

> It [the Siegfried Line] is a monument to human stupidity. When natural obstacles, oceans and mountains, can be readily overcome, anything that man makes, man can overcome.
>
> — George S. Patton, Jr., "Address to the Third Army Staff"

There is a new and emerging combat medium. It is a battlespace beneath the surface of the earth. This study will examine how the United States (U.S.) must adjust elements of its national security strategy to succeed in achieving military dominance within this as yet unofficially defined subsurface warfare domain. For decades, builders have constructed facilities designed to absorb the most punishing strikes. Today, across the globe, these underground assets are critically linked to nations' strategic Centers of Gravity (CoG) and protected by vast networks of subterranean infrastructure and facilities. Subterranean Infrastructure and Facilities (SIF) is a new composite term, devised to demonstrate the growing size and sophistication of underground fortification programs. These fortified complexes are currently used to house and protect some of the most dangerous threats to global stability.

Globally, potential adversaries are building ever stronger and deeper fortifications, many of which are largely immune to current the U.S. weapons inventory. The issue is not new. Military fortification has existed since man first sought shelter and safety from threats. Truly, fortification in one form or another is as old as our species. It has been a constant struggle between the besieged and the breachers to achieve

dominance. Today, depth and design have yielded dominance to those within the fortifications. Advanced construction and design techniques coupled with technological improvements in mining have forged the ideal protection of ultra-strong fortifications located at virtually unreachable depths. The day of the truly impregnable structure may be near. More compelling is that it is not a single adversary but rather a global issue. The global information commons, advancing mining and construction technology have combined to aid the builders of today's reinforced emplacements. The current military key terrain is not a dominant high point but rather the ability to dig, fortify and defend. What are required now are mechanisms to discourage the construction of the underground edifices and the capability to hold them at risk. Virtually no place on the surface of the earth is immune from the destructive reach of the U.S. That fact must now apply to the depths of the earth. Failure in this undertaking will grant our enemies control of a vital domain.

Through strategic, operational and tactical advantages associated with this complex target set, those who dig now dictate terms. Iran, North Korea, China, Pakistan and Russia have vast underground complexes. These and other nations have ongoing programs to expand existing facilities further and construct more, deeper and even harder structures. Entire underground hardened cities exist beneath mountains of granite. Many current weapons will shatter on impact with hardest rock formations. A few niche weapons can withstand the impact but only penetrate to limited depths. Nuclear weapons can hold some of these targets at risk, but are a weapon of last resort, virtually unusable due to the broader implications of their collateral effects. Clearly, a new approach is required.

The methodology of this thesis will be an exploratory study to identify how the U.S. must adjust elements of its national strategy to counter this development. The analysis and structure of this thesis is bound by several factors. First, in order to ensure the widest dissemination and largest possible audience, all subjects discussed and all references are unclassified. Due to subject matter classification and the unique nature of the topic, there are only limited amounts of unclassified technical data available on the current defeat measures and kinetic destruction program capabilities. However, there is a vast wealth of historical knowledge offered as counterpoint to the limited current day knowledge. The temporal bounds of the study address the period from World War II (WW II) through to the current day. Some sources (particularly those regarding nuclear weapons) had conflicting data and the author's best judgment was utilized to provide the most accurate portrayal of evidentiary facts. It seeks to identify expanded strategies and underscore new methods required to control the subterranean domain. To examine this in detail, the underground facilities and present countermeasures must be first examined. The newest construction and mining techniques currently favor the builder. The size and scope of potential adversaries' SIF presents potentially overwhelming challenges.

As previously stated, the balance between arms and armor is a historic race. To better address the current challenges, a historic model is required to better frame the issue. During WW II, the German military build a vast complex of fortifications. To counter this development, the Allies, pushed technology and creativity to its limits in order to attempt to subdue these key targets. What can be learned from this campaign and counter campaign of building and breaching when applied to today's challenges?

This work will examine the need for a holistic national effort, utilizing all of the elements of power and influence, through direct and indirect lines of means, to illuminate concepts and determine if dominance within the new domain is possible. What aspects of diplomatic, information control and economic power can be utilized to reach a position of dominance? From this analysis, several additional questions emerge and must be addressed. Are there underdeveloped technologies or conceptual methods to directly address the complex requirements and allow the demolition of these targets on an industrial scale? If military technological solutions are currently unavailable or unobtainable, what other efforts are required to field solutions to the problem set? Given current budget constraints and the limits of technology are there other adequate solutions to addressing the problem without the expense of developing new technologies? Are diplomatic and information control measures and economic tools alone sufficient means to gain dominance within this contested terrain? These questions coupled with the primary issue of SIF pose extremely intricate problem set.

Many creative and thoughtful minds are focused on the problem but technology and resources remain limited. The problem does not rest exclusively with weapon systems development. Rather, it requires a whole of government approach coupled with a demonstrated willingness to apply power and will to achieve dominance. It is truly an intricate problem that requires a multifaceted approach to find a workable solution. The objective end state will be reached when openly demonstrated capability exists to rapidly and accurately penetrate thousands of feet of earth, rock and concrete to surgically excise critical targets; there will be no terrestrial place to hide. If we fail to achieve this means, we fail to dominate a strategically critical domain.

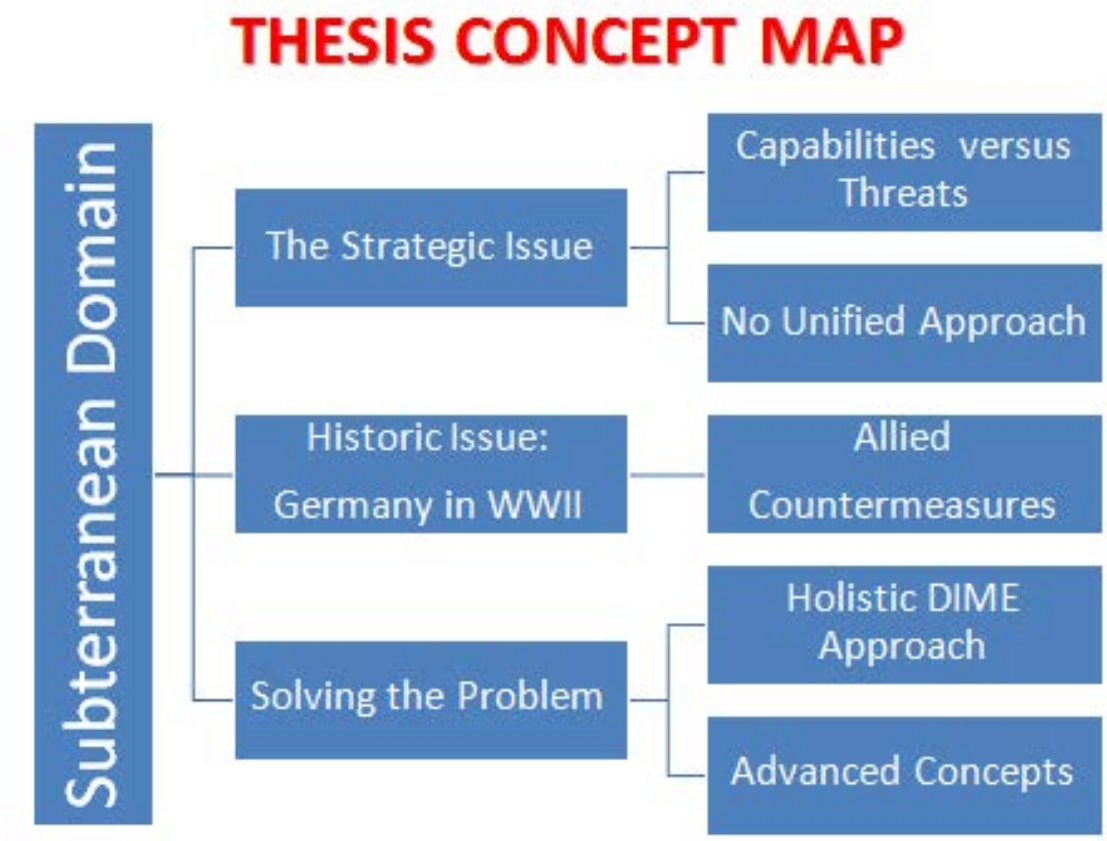

Figure 1. Thesis Concept Map

Source: Created by author.

Definitions

Due to the complex nature of the subject matter and broad unfamiliarity with many of the concepts associated with the thesis, important key definitions are listed below. These explanations should provide the relevant background information needed for clarity and understanding of the primary and secondary concerns of the thesis.

Center of Gravity (CoG): The source of power that provides moral or physical strength, freedom of action, or will to act.[1]

Defense Threat Reduction Agency (DTRA): The U.S. Department of Defense's (DoD) official Combat Support Agency for countering weapons of mass destruction.[2]

DIME (Diplomatic, Information, Military, Economic): Elements of national power.

Domain: An area of interest or an area over which a person has control.[3]

Hardened and Deep Buried Targets (HDBTs): HDBTs are defined as fixed, unitary, high value facilities or functions to which a potential adversary has applied a considerable structural reinforcement (hardening) or which have been constructed under the earth's surface (2+ meter) and subsequently covered with materials such as soil, gravel, rock, reinforced concrete, and the like, in order to frustrate attacks and intelligence collection efforts.[4]

Integrated Air Defense System (IADS): An IADS is not a formal system in itself but the aggregate of functional component air defense systems comprising sensors, weapons, C2, communications, intelligence systems, and personnel operating within an area. An enemy IADS could include detection, C2, and weapon systems integrated to protect those assets critical to achieving their strategic, operational, and tactical objectives.[5]

Intelligence, Surveillance, and Reconnaissance (ISR): An activity that synchronizes and integrates the planning and operation of sensors, assets, and processing, exploitation, and dissemination systems in direct support of current and future operations. This is an integrated intelligence and operations function.[6]

Key Terrain: Any locality, or area, the seizure or retention of which affords a marked advantage to either combatant.[7]

Mission Kill: An attack or damage inflicted by a weapon that does not destroy a military vehicle but results in it taking no further part in its intended mission.[8]

Overburden: (geology) The rock and subsoil that lies above a mineral deposit such as a coal seam.[9]

Rock Mechanics: Rock mechanics is the theoretical and applied science of the mechanical behavior of rock and rock masses; also compared to the geology, it is that branch of mechanics concerned with the response of rock and rock masses to the force fields of their physical environment. Rock mechanics itself forms part of the broader subject of geomechanics which is concerned with the mechanical responses of all geological materials, including soils. Rock mechanics, as applied in engineering geology, mining, petroleum, and civil engineering practice, is concerned with the application of the principles of engineering mechanics to the design of the rock structures generated by mining, drilling, reservoir production, or civil construction activity, e.g. tunnels, mining shafts, underground excavations, open pit mines, oil and gas wells, road cuts, waste repositories, and other structures built in or of rock. It also includes the design of reinforcement systems such as rock bolting patterns.[10]

Weapons of Mass Destruction: Chemical, biological, radiological, or nuclear weapons capable of a high order of destruction or causing mass casualties and exclude the means of transporting or propelling the weapon where such means is a separable and divisible part from the weapon.[11]

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[1]Department of Defense (DoD), Joint Publication (JP) 1-02, *Department of Defense Dictionary of Military and Associated Terms* (Washington, DC: Government Printing Office, 8 November 2010 as amended through 15 August 2012), 45.

[2]Defense Threat Reduction Agency, “About DTRA/SCC-WMD,” http://www.dtra.mil/About.aspx (accessed 28 November 2012).

[3]Cambridge Academic Content Dictionary, “Domain,” http://www.cambridge.org/us/esl/catalog/subject/project/item404966/cambridge-academic-content-dictionary/?site_locale=en_US (accessed 28 November 2012).

[4]Global Security.org, “Hard and Deeply Buried Targets (HDBTs),” http://www.globalsecurity.org/wmd/intro/bunker.htm (accessed 28 November 2012).

[5]Department of Defense, Joint Publication (JP) 3-01, *Countering Air and Missile Threats* (Washington, DC: Government Printing Office, 23 March 2012), 20.

[6]DoD, JP 1-02, 162.

[7]Ibid., 185.

[8]Wiktionary, “Mission Kill,” http://en.wiktionary.org/wiki/mission_kill (accessed 28 November 2012).

[9]Richard Fortey, *The Earth* (New York: Knopf Publishing, 2011), 163.

[10]Wikipedia,”Rock Mechanics,” http://en.wikipedia.org/wiki/Rock_mechanics (accessed 28 November 2012).

[11]DoD, JP 1-02, 341.

CHAPTER 2

LITERATURE REVIEW

> He took his time. Had he known that he was about to enter a tunnel whose only egress was his own annihilation, would he have turned away? Perhaps. Perhaps not. Who can tell?
>
> ― Arundhati Roy, *The God of Small Things*

Overview

This literature review will focus on the primary writings associated with SIF. It will be subjugated by topics which parallel the research methodology outlined in chapter 3 and the primary findings identified in chapter 4. The subtopics of the current SIF issue include: U.S. National Security Documents, present U.S. capabilities, arms control treaties and international protocols, German fortification efforts and Allied countermeasures during WW II, and finally, prospects for new approaches utilizing the holistic elements of U.S. national power. Sources are evaluated and weighted based on thesis impact, overall significance and if the sources will be able to address the following three questions in relation to the literature: (1) What do we already know about the new subterranean warfare domain?; (2) What are the characteristics of the key concepts or the main factors or variables associated with achieving dominance within this domain?; and (3) of the current information available, what is lacking, inconclusive, contradictory or too limited?

U.S. National Security Documents

The core U.S. national security documents (*United States National Security Strategy,*[1] *The National Military Strategy of the United States of America,*[2] the 2008

National Defense Strategy[3] and the 2010 *Quadrennial Defense Review Report*[4]) are examined to clarify the nation's overall strategic approach and to determine if the issue of underground fortifications has been identified as a significant security issue. Unfortunately there is no direct or indirect reference of the need to addresses the expanding problem of hardened and deeply buried targets in any of the core documents. Additionally, *The JOE 2010, Joint Operating Environment 2010,*[5] which is a forward-looking strategic assessment of the most likely global problems necessitating U.S. intervention, also fails to mention SIF as an emerging issue.

Present U.S. National Capabilities

Based on the information available through Unclassfied sources, there is a wealth of data regarding the current and near-term kinetic approaches to destroying or holding at risk a wide variety of hardened and deep buried targets. However, most of the information obtained is narrowly focused. For example, Jonathan Ernest's *Nuclear Weapon Initiatives: Low Yield R & D, Advanced Concepts, Earth Penetrators, Test Readiness* looks at the nuclear weapons development options recently reviewed by the U.S. It outlines the potential for Robust Nuclear Earth Penetrator (RNEP) weapons and the associated political dynamic of their development and use. Overall, the work provides valuable insight into the complexity of the deep target problem and the difficulties associated with many of the solutions. Similarly, *Space Weapons, Earth Wars* by Bob Preston, Dana Johnson, Sean Edwards, Michael Miller and Calvin Shipbaugh is a potential look into the non-nuclear options of the near future. The work examines the range of military options and applications presented if space weapons are selected to address deep underground targets. It also highlights the nuances of certain treaty

language. Specifically, space-to-space and space-based nuclear weapons are considered non-treaty compliant. However, space-to-terrestrial weapons are permitted within the confines of the existing treaty architecture. These two sources outline what can be done within the confines of the current capabilities and only require a higher level of national commitment.

The current conventional kinetic capabilities are addressed through several sources. As recently as 28 January 2012, the *Wall Street Journal* reported that the Department of Defense (DoD) had concluded that the GBU-57/B Massive Ordnance Penetrator (MOP) was not capable of destroying certain facilities in Iran and had submitted a request for funds to upgrade the weapon. The request reportedly sought to improve the weapon's penetrating characteristics. The MOP began as a technology demonstration program funded by the Defense Threat Reduction Agency (DTRA). The program envisioned developing a 30,000-pound conventional penetrating weapon that will defeat a specialized set of hard and deeply buried targets. The MOP is designed specifically to attack hardened concrete bunkers and tunnel facilities. Designed to be delivered by B-2 and B-52 strategic bombers from high altitudes, the MOP's innovative design features include a Global Positioning System navigation system to ensure precise target impact. MOP is designed to go deeper than any previously fielded non-nuclear bunker buster. It was optimistically speculated to be able to penetrate as much as 60 meters (200 feet) through 5,000 pounds per square inch (PSI) reinforced concrete, and 8 meters (25 feet) into 10,000 PSI reinforced concrete. If these published results are actually achievable, the weapon has great operational potential. In parallel, but drawing less publicized attention has been the U.S. Navy program to modify Submarine Launched

Ballistic Missiles (SLBM) for non-nuclear time sensitive strike roles. Published documents define the Conventional TRIDENT Modification (CTM) as being able to launch a maneuverable hypersonic boost-glide vehicle with the capability to deliver precision conventional effects with global reach (~9000nm) within one hour. The payload throw-weight is approximately one ton, with various payload configurations including multiple precision guided sub-munitions, a unitary penetrating munitions, and/or sensor packages. The literature on these two weapon systems highlights the fact that given adequate funding and high-level support, various technological advancements to address the subterranean problem are possible. It appears that funding instead of physics and will rather than imagination are creating barriers to operational capability.

The published data on these two maturing weapons is complimented by Dale Knutsen's *Strike Warfare in the 21st Century, an Introduction to Non-Nuclear Attack by Air and Sea*. This work examines the U.S. Navy's current and near-term approach to servicing a wide-range of targets to included hardened and deep buried targets (HDBTs) with non-nuclear munitions. Overall, the work provides valuable insight into the complexity of the non-nuclear targeting problem and the difficulties associated with many of the solutions, particularly the restrictions associated with sea-based systems. However, the U.S. Navy's role is limited compared to the potential scale of U.S. Air Force operations against the same targets. Carrier strike aircraft and Sea Launched Cruise Missiles (SLCM) simply do not have the same range and payload as their shore based counterparts. Unfortunately there does not appear to be a single source publication available at this time which summarizes in detail, all of the current U.S. unclassified initiatives focused on solving the underground calculus.

In contrast to potential military solutions are the extremely rapid advancements of excavation and mining technology which are precipitously opening the subterranean domain. Driven by economic and technological breakthrough, vast underground frontiers are now unlocked. In January of 2012, *Popular Science* published Xan Rice's article "Deeper." This magazine exposé provides a look at the current and near-future industrial state-of-the-art for deep mining and advanced tunneling technology. It sets the parameters for depth and scale of underground construction for the near-term. It also peripherally highlights the potential issues of strategic knowledge protection and dual-use technology transfer. The article serves as an indicator of the challenges to a whole-of government approach to addressing the problem through non-military means. Mine equipment makers Herrenknecht, Atlas Copco's and Aker Wirth's Shaft Boring System (SBS) Tunnel Boring System (TBS) offer the viable potential for tunneling to depths as great as 14,500ft.[6] Additionally, these same companies are proposing rapid tunneling systems to easily access deep void spaces and rescue miners trapped in cave-ins.[7]

Arms Control Treaties and International Protocols

Fortification, as a means of military power, has not been without its diplomatically negotiated limitations. The 1920s Washington Naval Conference was significant in that, for the first time, restrictions were established on national military force structures over a set period of time and mutually agreed upon by all concerned participants. The crucial linkage to SIF was Article XIX,[8] which is often referred to as the "Fortification Clause." This article prohibited Britain, Japan and the U.S. from enhancing their existing fortifications and also prohibited them from building any new naval bases in the Pacific region. Never before had a group of nations mutually agreed

not to passively defend their territories through the use of fortification. This was precedent setting and can be used a model for future diplomatic efforts to restrict the continuum of deep underground structure fabrication.

Additionally, from the Cold War through the current day, there have been a series of strategic arms limitation and reduction treaties between the U.S. and Russia (previously: the Soviet Union). These protocols restricted virtually all aspects of the nuclear arms race. These treaties: Strategic Arms Limitations Talks I (SALT I) (1969-1972), the Anti-Ballistic Missile (ABM) Treaty (1972), SALT II (1972-1979), the Intermediate-Range Nuclear Forces Treaty (1987), Strategic Arms Reduction Talks I (START I) (1991), START II (1993), New START (2010), Space Weapons Treaty (year), and the Open Skies Treaty (2002), offer potential insights into restrictions on destabilizing military programs. The Non-Proliferation Treaty or NPT is another critical international treaty to which the U.S. is a signatory member. The NPT is an international treaty designed to prevent the spread of nuclear weapons and weapons technology. Additionally, it aims to promote cooperation in the peaceful uses of nuclear energy and to advance the objective nuclear disarmament. The Treaty went into force in 1970 and was extended indefinitely in May of 1995. More countries have ratified the NPT than any other arms limitation and disarmament agreement in history. These diplomatic endeavors are extremely valuable to the greater context of the thesis on two levels. First, it is historical proof that militarization of a domain (sea, ground or space) can be destabilizing and that involved parties can agree to limitations enforced by treaty. Second, these treaties incorporated some level of intrusive inspection and monitoring which again

offers the possibility that similar mechanisms can be pursued to with regards to underground facilities.

Despite a rich amount of information regarding various associated penetrating weapons and diplomatic agreements, there are still knowledge gaps. Specifically, what is truly lacking in literature is a comprehensive overview of individual national programs. Due to the sensitive nature of these programs, much of the desired information is classified by the associated national governments and therefore unobtainable. However, given the explosive growth of the issue in recent years it is surprising that there is very little written word on the subject. Despite the sparse reporting, one country has specifically outlined its program goals. The Chinese government has published a technology acquisition roadmap. The document, officially known as *China's National Medium- and Long-Term Program for Science and Technology Development (2006-2020),*[9] was published by the State Council in February 2006. The language with the documents outline the Chinese plan to utilize whole of their government to not only advance China economically but also include significant military related technology which will improve the already vast Chinese program. Likewise the DoD's *Annual Report to Congress, Military and Security Developments Involving the People's Republic of China, 2011* outlines overall Chinese military expansion and specifically mentions the growth of the Chinese Underground Facilities network.[10] Overall, the available literature presents some degree of narrowly focused military options available and hints of the subterranean issue. Without broader references, it is difficult to characteristics true scope of the global underground systems. Finally, the current literature does not address any

plans to utilize the other elements of nation power which may be employed as enablers for success.

German Fortification Efforts and Allied Countermeasures during WW II

These sources are primarily used to support the historic case study portion of the thesis. The intent of this case study is to address the issue of hardened fortifications as part of a larger warfighting effort. During WW II, the German military built a vast array of fortifications. Specifically, it was the German efforts to protect leadership, strategic V-weapon sites and U-boat pens which yielded the greatest challenges to the Allies. These sites were incredibly well constructed and most survived extremely intense bombardment and remain standing to this day. The Allies, for their part, pushed technology and creativity to its limits to counter these key targets. Their extreme efforts produced only marginal effects. The elemental difficultly with utilizing historical cases studies, particularly when technology is a key driver, is the fact that conditions and technical limitations have changed over time. These sources review German military fortification efforts from before World War I (WW I) through the end of WW II. The four most important works reviewed are *Barnes Wallis' Bombs*[11] by Stephen Flower, *Hitler's V-Weapons Sites*[12] by Philip Henshall, *Fortress Third Reich, German Fortifications and Defense Systems in World War II*[13] by J.E. Kaufmann, J.E and H.W. Kaufmann and Gordon Williamson's *U-Boat Bases and Bunkers 1941-45*.[14] These works effectively outline the scope of the German fortification program and the Allied effort counter it.

Barnes Wallis' Bombs outlines the model of the Allied approach of dealing with the German fortifications in WW II. Specifically, it addresses the political and

technological efforts applied to solving the problem of countering the strongest German targets with air-dropped ordinance. This work can also be viewed as a potential blueprint for today's efforts. *Hitler's V-Weapons Sites* represents the counter-point to the allied effort. It presents the details of German V-Weapon sites which were constructed using the most advanced engineering and design techniques available to Germany during the war. It is a critical work not only for its historic value but it also illuminates the efforts which countries will apply to protecting their most valuable strategic infrastructure. Likewise, Kaufmann and Kaufmann's *Fortress Third Reich, German Fortifications and Defense Systems in World War II* provides an insightful overview of the entire German fortification program. It is extremely valuable in its depth and scope of coverage of the historical issue. It sheds valuable light on the economics of a huge continent-wide system of fortifications and the construction program which generated it.

Supplementing these works are the Germany focused Osprey Publishing Fortress series of books. These works each focus on a specific element of the German fortification system. *U-Boat Bases and Bunkers 1941-45,* has a wealth of knowledge and information on the hardened German submarine pens. These targets were largely immune to the heaviest conventional bombardment and only with the development of advanced aerial bombs were these targets finally rendered vulnerable. The book supports the thesis by providing both historical perspective and indications of the limits of current penetration weapons. *German V-Weapon Sites 1943-45* has a series of superb illustrations on the hardened German V-Weapon sites. These graphics will provide tremendous supporting visualization of the hardened sites and enable the thesis consumer to better understand the complexities of the issue. It also supports the thesis by providing through its historical

perspective an indication of the lengths nations will go to in order to protect their strategic weapons. *The German Fortress of Metz 1870-1944*[15] work provides background and insight into the overall approach utilized by Germany with regards to its military fortification projects. It supports the historical model utilized within the thesis. The highly illustrated *Fort Eben Emael, The Key to Hitler's victory in the West,*[16] focuses not on German construction efforts but rather the German approach to defeating the Eben Emael Fortifications. It demonstrates that innovative techniques can lead to breaching of any fortification regardless of its strength or design. Further works from the series include *The Fuhrer's Headquarters, Hitler's command bunkers 1939-4,5*[17] which examines the German ultra-hardened leadership fortifications developed to ensure the German national command authority (Hitler) had well-protected hardened fortifications from which he could exercise command and control of the German war machine. *The Channel Islands 1941-45, Hitler's Impregnable Fortress,*[18] examines the German efforts to construct ultra-hardened fortifications within the English Channel to counter the threat of Allied invasion of France. Similarly, *D-Day Fortifications in Normandy*[19] addresses the German fortifications system developed in Normandy to counter the threat of an Allied invasion of France. *The Atlantic Wall (1) France*[20] and *The Atlantic Wall (2) Belgium, The Netherlands, Denmark, and Norway,*[21] is a two volume set which delves into the systematic method utilized by Germany to employ fortifications guarding the extensive European Coastline from the threat of Allied invasion. Both works have excellent illustrations, not only of the finished works but also illustrations of their actual construction as well.

The last German related publication was T.D. Dungan's *V-2, A Combat History of the First Ballistic Missile,*[22] is a historical review of the German V-2 weapon system. The work demonstrates that for every measure there is sometimes an equally innovative countermeasure. Specifically, while the fixed V-2 sites were under sustained Allied bombardment, the Germans' developed road-mobile transporter, erector launchers which were extremely difficult to find and target with existing technology. It is an important work not only for its historic value but it also illuminates the efforts which counties will apply to protecting their most valuable strategic infrastructure.

Finally, an American weapon system, under development at the close of the war, is examined. The T-12 Cloudmaker[23] penetrating bomb was developed by the U.S. from 1944 to 1948. It was designed to attack targets invulnerable to conventional "soft" bombs, such as bunkers and viaducts. It achieved this by having an extremely thick nose section, which was designed to penetrate deeply into hardened concrete structures and then detonate inside the target after a short time delay. This created an "earthquake effect." The T-12 was a further development of the concept initiated with the United Kingdom's Tallboy and Grand Slam weapons: a hardened, highly aerodynamic bomb of the greatest possible weight designed to be dropped from the highest possible altitude. Penetrating deeply in the earth before exploding, the resulting shockwave was transmitted through the earth into structures. The resulting camouflet could also undermine and collapse structures. The bomb could also be used against hardened targets. The weapon was never operationally deployed due to the introduction of nuclear weapons.

Overall, the WW II literature serves as an extremely useful model for both fortification construction and demolition counter measures. Within the relatively short

span of the conflict, structures became significantly more robust and substantially more difficult to destroy. Likewise, the technological efforts applied to destroying these targets advanced the kinetic bombardment state-of-the-art. As a model, it presents an opportunity to postuate on what might be possible if similar efforts and resources were applied to today's challenging targets.

Prospects for New Approaches Utilizing the Holistic Elements of U.S. National Power

There is little if any current literature which outlines the future prospects for new approaches utilizing the composite elements of national power to address the need for dominance within the subterranean realm. This absence of writing presents an opportunity to explore and define the new approaches. However, it also represents a limitation because of the singular perspective of the author and the limits of his imagination. Hopefully, this thesis will inspire debate and critical thinking which will compel true subject matter experts to publish their concepts and visions.

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CHAPTER 3

STUDY METHODOLOGY

> The art of conducting sieges has become a calling like those of the carpenter and shoemaker.
>
> — Frederick the Great,
> "The King of Prussia's Military Instructions to His Generals"

The methodology of this thesis is an exploratory study seeking to define and characterize the new subterranean combat medium. It seeks to identify how the U.S. must adjust elements of its national security strategy to achieve dominance within the subterranean domain. The *Cambridge Academic Content Dictionary*[1] defines a domain as an area of interest or an area over which a person has control. There exists a new and challenging warfighting domain beneath the ground. For decades, builders have constructed facilities designed to absorb the most punishing strikes. Today, across the globe, nations' strategic CoG are protected by SIF. Thus, the research model for this work will first define the strategic issue, review the scope of global underground fortification archetucture and finally, review the current means for addressing the overall matter.

Secondly, a historic case study, which addressed the same issue as part of a larger warfighting effort, is presented to provide historic parallel. During WW II, the German military built a vast array of fortifications, these included expansive the Atlantic Wall and other impressive military construction projects. However, it was the German efforts to protect leadership, strategic V-weapon sites and U-boat submarine pens which yielded the greatest challenges to the Allies. These sites were incredibly well constructed and many survived extremely intense bombardment and remain standing to this day. The

Allies pushed technology and creativity to its limits to counter these key targets. However, their innovative efforts produced only marginal affects. The elemental difficulty with utilizing historical cases studies, particularly when technology is a key driver, is the fact that conditions and technical limitations have changed over time. Ultimately, the historic model remains a valid and effective tool for explaining the present situation.

This work will also examine the potential for a holistic national effort utilizing all of the elements of national power (DIME), in direct and indirect efforts, to illuminate pontential concepts to determine if dominance within the new domain is a fesable endevour.

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[1]Cambridge Academic Content Dictionary, “Domain.”

CHAPTER 4

FINDINGS AND ANALYSIS

> By carrying the destructiveness to a suicidal extreme, atomic power is stimulating and accelerating a reversion to the indirect methods that are the essence of strategy – since they endow war with intelligent properties that raise it above the brute application of force.
>
> — B. H. Liddell Hart, *Strategy*

SIF is a new and as yet, informally recognized warfare domain. This chapter will examine SIF in detail, explaining why the issue is becoming more complex. It will also review current U.S. perceptions of the issue and its active strategic approach (or lack thereof) to the problem. Using the historic example of the German fortification in WW II and the Allied countermeasures to this most intricate and formidable defensive network, what lessons can be learned and applied to the current problem? The narrow trap of a military-only solution to problems will also be highlighted. This will moves closer to determining how the U.S. can best address the threat posed by the global subsurface target set. Finally, a summation of national security requirements should compel revision and a holistic approach to the solving the problem of subterranean domain control.

Currently the U.S. does not perceive SIF to be a specific strategic issue. None of the core U.S. national security documents, *United States National Security Strategy,*[1] *The National Military Strategy of the United States of America, 2011,*[2] the 2008 *National Defense Strategy,*[3] and the 2010 *Quadrennial Defense Review Report*[4] make any specific mention of the need to address the expanding problem of hardened and deeply buried targets. These core writings outline the strategy and plans for the U.S. to retain military supremacy on land, sea, air and within the cyber domain. Unfortunately, this framework

of national strategy and policy fails to mention or even provide the slightest acknowledgement of the critical issue of underground fortifications and facilities. There is no national level appreciation for this new domain and correspondingly there are unmet requirements to achieve active dominance over it. Even more insightful into this lack of appreciation for the subterranean domain is the omission of any mention of hardened deep facilities within "The JOE 2010, Joint Operating Environment 2010."[5] This document is designed to be a forward-looking examination of future conflict domains and strategic situations. It is a primer for potential future military operations and issues. This is especially ironic since the subterranean domain impacts all warfare domains, including the recently materialized cyber domain. The subsurface realm is critical because SIFs potential adversaries are afforded physical protection from within for the systems and mission command from which to challenge U.S. military supremacy.

In order to appreciate the complexities of this new war fighting arena, it must first be characterized. While the issue of fortification is not new, what are new are the enabling technologies to build facilities of a significantly greater depth, scale and complexity. These enablers include massive and extremely efficient Tunnel Boring Machines (TBMs) with huge cutting faces able to penetrate all but the hardest of underground rock formations. More concerning is the prospect of the advanced mining technology now beginning to enter service in mines around the world. Mine equipment makers Herrenknecht, Atlas Copco's and Aker Wirth's Shaft Boring System (SBS) Tunnel Boring System (TBS) offer the viable potential for effectively tunneling down to depths as great as 14,500 feet and economically extracting mineral deposits.[6] Additionally, these same companies are proposing a rapid tunneling system to extract

miners trapped in cave-ins[7] and other deep collapsed spaces. This same technology has significant military potential. For example, this deep mining machinery has the ability to allow for rapid new tunneling, dig-out from collapsed spaces, and to create new openings or alternate accesses to existing facilities.

Today, with advanced mining and construction methodologies, tunnels can be pushed through bedrock, lined with high strength, high performance concrete at depths significantly greater than ever before. However, the most complex factor is that it is not a single adversary pursuing this capability, but rather a global advancement of this capacity. Coupled with this fact is the networking of these facilities into massive complexes and even nationwide integrated systems of underground facilities. With deep directional drilling over vast distances, these complexes can be digitally and even physically linked via conduits too deep to easily interdict or cut. Most frightening of all, none of the technology required to build this infrastructure is considered restricted or dual-use as in the case of nuclear, chemical and biological agent research and production capabilities. It is not simply the underground facilities but the systems within these redoubts which further secures them. For example, efficient independently operated power generator systems can create a stable power source to run command and control architecture, uranium centrifuges, biological agent incubators, computerized milling systems and other sensitive technologies. Fundamentally, any critical technology can be placed out of reach and effectively operated in an environment, largely immune to any outside effects. This is the relevant aspect of the subterranean domain and it must be addressed.

Key Terrain is defined as any locality, or area, where the seizure or retention of which affords a marked advantage to either combatant. Historically, the key terrain has always been the high ground, usually a piece of elevated terrain which better supports effective military tactics. Joint Publication (JP) 1-02 defines key terrain as "any locality, or area, the seizure or retention of which affords a marked advantage to either combatant."[8] Today, the current military key terrain is not a dominant high point but rather the ability to dig, fortify and defend. The prevailing topography is now encased in concrete and bedrock.

One of the hallmarks of American military strategy is the ability to hold at risk an adversary's CoG. JP 5-0 identifies a CoG as a source of strength, power, and resistance.[9] Unfortunately, with the vast expansion and improvements in SIF, previously threatened CoGs are becoming immune to pressure. Countries can now place their elements of power beyond the reach of U.S. might and influence. Without improvements to counter-SIF efforts, this is negatively affecting the manner in which the U.S. is able to conduct its military operations, campaigns and wage its wars.

Globally, potential adversaries such as China, Russia, Iran, North Korea and Pakistan are building ever more complex, stronger, and deeper fortifications which are largely immune to the current U.S. non-nuclear weapons inventory. In the simplest terms, bunkers and other Underground Facilities (UFACs) are the preferred method of protecting a nation's most valuable assets. Just as one puts a safe in a house or a vault in a bank, precious national commodities are sheltered. In order to better understand and appreciate the complexity of the issue, the analysis must examine the problem at

elemental levels. First the characteristics of a bunker will be examined followed by progressive expansion of the problem to UFACs, and finally to national level SIFs.

What exactly do these national asset protection systems look like? In the crudest terms, they are bunkers; inherently more complex and sophisticated, but bunkers nonetheless. What are the physical services provided by a bunker to its users and how has it evolved based on the threats? Blast protection is the obvious basic commodity. Blast protection is designed to deflect the blast wave from nearby explosions to prevent ear and internal injuries to those within the structure. While frame buildings collapse from as little as three PSI of overpressure, bunkers are regularly constructed to survive several hundred PSIs. This substantially decreases the likelihood that a weapon strike (other than a bunker buster) can harm the structure. The basic effort in the design and construction of a bunker is to provide a structure that is very strong in physical compression. The most common purpose-built structure is a buried, steel reinforced concrete vault or arch. Some bunkers are designed to also provide protection from large ground shocks, and therefore must have sprung internal buildings or other integral shock protection to protect inhabitants and internal mechanisms from the walls and floors. In order to provide protection from the effects of nuclear weapons, bunkers must also cope with the underpressure that lasts for several seconds after the shock wave passes, and block radiation. Usually these features are easy to provide. The overburden (soil and rock) and structure provide substantial radiation shielding, and the negative pressure wave usually only constitutes about one-third of the strength of the overpressure wave.

The basic cell or box of the bunker structure must be accessible in a manner so as not to reduce or impair the overall strength of the structure. Therefore, doors or other

access points must be introduced into the vault. Engineering structural objectives require that the doors must be of the same relative strength as the walls. However, to reduce the weight, the door is normally constructed of steel, with a fitted steel liner and frame. If the door is on the surface and will be exposed to the blast wave, the edge of the door is normally counter-sunk in the frame so that the blast wave or a reflection cannot lift the edge and expose the facility to damage and destruction. Ideally, a bunker should have multiple access points. However, there is an element of diminishing return, as more openings impair the structural strength and overall design integrity. In bunkers designed to be inhabited for prolonged periods, large amounts of ventilation is essential to prevent the ill effects of heat and poor air quality. Independent power sources to support airflow and designed mission activity are also required. Multiple levels of redundancy are inherent in the designs as well. All openings in a bunker must be protected by blast valves to ensure pressure waves and contaminants cannot enter the facility.

These basic structural points serve as the design building blocks for UFACs. UFACs expand the basic bunker structure into a more complex operating system which due to intent, design, location and size is significantly more refined. There are six basic types of UFACs in two broad segments.

Above Ground and Cut and Cover Facilities

This structure is hardened by using soil, concrete, and rock atop the structure once it has been built. These facilities are often built into an excavation and then covered. There are five generic types of Above Ground and Cut and Cover facilities:

Aboveground Bunker

A structure is aboveground when all or a portion of the structure projects above the ground. Structures mounded over with slopes steeper than 1:4 are considered aboveground. With respect to the ground surface, a structure is flush or partially buried when its rooftop is flush or buried less than half the structure diameter.

Aboveground Covered Bunker

This type of facility is a hardened facility constructed at or near the surface level. Of all UFACs, it is the easiest to construct. However, it is also one of the simplest to identify and defeat with the current penetrating weapon technology. Additional protection is usually provided by visually deceptive measures and adjacent Integrated Air Defense System (IADS).

Shallow Underground Complex

This type of facility is a hardened structure constructed at or near the surface level then covered with overburden to provide additional protection (cover and concealment).

Basement Bunker

This type of facility is similar to the Shallow Underground Covered Bunker. However, it is placed beneath a building or other structure. Instead of overburden, the building itself provides the cover and concealment. The building may or may not be related to functions of the bunker. In addition to the structure providing additional protection, the functional nature of the building may also provide an additional level of passive protection. For example if the cover structure was a hospital or religious facility it

would likely impact targeting requirements, weapon selection and collateral damage concerns.

Shallow Accessible Bunker/Silo Complex

This type of facility is usually a vertical shaft or shallow box (coffin structure) with a cover or door, encased in several feet or meters of reinforced concrete. Although a relatively shallow structure and easy to identify, most missile silos are designed to survive close proximity nuclear strikes. During the Cold War, some Intercontinental Ballistic Missile (ICBM) silos could withstand greater than 10,000 PSI blast and shock effects.

Deep Shaft Facilities and Tunnels

This type of facility is protected by the existing rock and soil. There is a depth threshold at which it becomes more economical to tunnel rather than to excavate and cover. Below this threshold, costs generally are constant regardless of the depth of the tunnel below the surface, so tunneled facilities can achieve functional depths of hundreds of meters. For this reason, tunnels often are referred to as deeply buried facilities.

Deep Underground Complex

This is a deep shaft facility commonly referred to as Hard and Deep Buried Targets (HDBTs). This type of facility is most challenging to fabricate due to the physical depth and technological challenges of construction. However, it is also most difficult to defeat. These facilities can be placed beneath mountains or in hollowed-out void spaces at depths of 2,000 feet or greater below the surface. Despite the survivability

provided by the depth, Deep Underground Complexes are vulnerable to access interdiction even if the primary mission space itself is unassailable.

Tunnel Complex

This type of facility is usually a horizontal shaft or tunnel set into a mountain or other similar terrain future. The characteristics of terrain feature and the length of the tunnel provide the bulk of the protection. The entrance represents the greatest point of vulnerability and potential for interdiction. The layout of a deeply buried hardened tunnel may vary significantly from long, straight tunnels to the ones with multiple intersections, expansions, constrictions, chambers, rooms, alcoves, and multiple levels.

Tunnels are a tremendous operational ordeal. The deepest tunnels cannot be physically defeated with the current inventory of conventional munitions.[10] Therefore, a variety of weapons options and damage or functional-kill mechanisms are required. One of the options is to attack the tunnel portals with weapons that penetrate into or through the thinner cover rock above the portal or through the exterior doors, resulting in an internal detonation. This internal detonation focuses the blast and generates a severe pressure wave within the tunnel system. The overburden above the tunnel contains the explosive energy. The airblast propagation within a confined area, such as a tunnel, is significantly increased over that found in the open air. If the airblast environment is sufficiently severe, considerable damage to the mission space is more probable. The physics of the effect aid to increase the probability of inflicting damage. However, physics is universal and there are measures such as U-shaped accesses with multiple openings which can vent the blast effects. This can prevent even multiple weapon hits from inflicting the required damage even if the weapons actually detonate within a

tunnel. By adding internal blast doors, bomb traps and other energy sumps, the effect of most penetrating weapons can be easily countered with intelligent design and construction concepts, which add little to overall cost and complexity of construction.

The HDBTs are the ultimate expression of the subterranean fortification. They are defined as fixed, unitary, high value facilities or functions to which a potential adversary has applied a considerable structural reinforcement (hardening) or which have been constructed under the earth's surface (2+ meters) and subsequently covered with materials such as soil, gravel, rock, reinforced concrete, and the like, in order to frustrate attacks and intelligence collection efforts.[11] Overall, the primary objective of any hardened structure is to withstand the effects of hostile weapons and complete the missions for which it was designed. The term "hardened" applies to structures intentionally designed to be resistant to conventional and nuclear weapons effects, chemical or biological attack, and intruder attack. Deep-buried installations can be made almost invulnerable and are generally used for protection of large one-of-a-kind facilities such as command and control centers, which cannot risk relying on redundancy or dispersion to ensure operability.

The overall problem of UFACs grows enormously more complex when individual facilities are networked as part of a greater system. This concept includes mutually supportive effects from multiple facilities. In the case of SIF, the whole is greater than the sum of its parts. The system of systems concept forces an adversary to strike the network as a whole in order to degrade the entire SIF complex. A simple analogy of the nature of the issue would be to compare protozoa, a spider and a starfish. Consider a county's underground facilities are living organisms. The protozoan is the simple bunker. The

spider would be a county's un-networked UFACs. Nonintegrated and lacking in system-wide redundancy, it is vulnerable. Finally there is the starfish, the integrated, yet decentralized[12] system of systems where the destruction of one has little effect on the greater whole. The only way to effectively kill the starfish is to inflict substantial damage throughout the whole organism, near simultaneously. It represents the greatest operational challenge and perhaps beyond the current non-nuclear U.S. capabilities.

This notion is applicable not only to a single UFAC but some countries' entire SIF network. Another factor adding further stress to the problem is the concept of rapid dig-out. The global mining industry is introducing a host of new technology to rapidly reach trapped miners in the event of a cave-in. That same technology can be prestaged within a UFAC and can permit rapid tunneling along both vertical and horizontal axis's from within to rapidly create new exits and reopen entrances previously closed by strikes. Given all of these factors and progressive advances in mining technology and underground construction techniques, today, the advantages lies with the defenders.

Penetrators: A Basic Concept Overview

During WW II, both the Germans and the Allies developed and tested various penetrating weapons including the so-called "Roeschling Round" (German), and the several versions of a very large Semi-Armor Piercing (SAP) bombs. However, despite successful military utilization, the technology of penetration mechanics was in its infancy.

The physical forces behind penetration subject the penetrator to both high positive and negative longitudinal acceleration forces, as well as rotational acceleration forces, during its brief flight. The device may be subjected to a positive acceleration on the order

of 5,000 Gs (one G equals the force of gravity) during launch by a missile or gun, and it may be subjected to a negative acceleration on the order of 20,000 Gs upon impact with a hardened target. Penetration of hard targets is achieved by concentrating a high amount of kinetic energy (KE) on a small area to create a very high stress. The use of heavy metal penetrators, such as Tungsten (which has a density about twice that of steel) allows the KE to be doubled while keeping the outer dimensions of the penetrator constant, thereby penetrating the target to a much greater depth. Because of these extreme loads and stresses, it is preferable that the weapon case be of monolithic construction (formed from a single piece of hard material) and made of a high-strength alloy. The use of monolithic construction eliminates joints and fasteners that are possible failure points in multipart cases. An example of a monolithic penetrator currently in use as an anti-tank weapon is the class of sub-caliber solid depleted uranium or tungsten “darts” that are conveyed by a sabot during gun launching.

Current penetrating weapons have been used successfully at low velocities against hard targets such as competent rock and concrete, or at high velocities against soft targets such as soil. Designing penetrators that can pierce deeply and survive the impact with hard targets at velocities in excess of 2,000 feet per second (FT/S) has been found to be particularly difficult. High velocity impacts with hard targets can cause severe nose abrasion, bending, and frequent breakage.

Defeat of hard and deeply buried targets continues to be of great interest due to the ever-increasing challenge of destroying enemy assets housed either in tunnels or in deeply buried bunkers. Hardening techniques include construction of facilities, many of which are deep underground with multiple layers of reinforced concrete, rock rubble,

and/or earth overburden. In general, two avenues are available for destroying targets of these types: increase in the sectional pressure (weight) of a penetrator and increase in penetrator impact velocity. Increasing penetrator weight is done by using “dense metal ballast” i.e. some metal at least twice the density of steel, such as Depleted Uranium or Tungsten. This is not an attractive choice, since this is counter to the trend toward smaller, more mobile weapon systems. Therefore, an increase in impact velocity is the more desirable alternative. To survive high velocity impact and destroy a hard or deeply buried target, the casing materials must exhibit excellent yield tensile strengths, elongation, and toughness values.

The current U.S. penetrating weapon inventory offers only limited weapon and employment options for dealing with a nationwide SIF complex. The ultimate weapon effects are extremely limited against an intricate national level SIF program.

What capability does this actually offer the U.S. in terms of overall capability? The newest penetrator weapon to enter the inventory, and perhaps the one with the greatest expectations assigned, is the GBU-57/B MOP On 25 July 2012, Air Force Secretary Michael Donley stated if required the GBU-57/B MOP would be available for use, though testing of the weapon to refine its capabilities was continuing. The MOP is a technology demonstration program funded by the DTRA to develop a 30,000-pound conventional penetrating weapon that will defeat a specialized set of hard and deeply buried targets. The MOP is designed specifically to attack hardened concrete bunkers and tunnel facilities. Designed to be carried aboard B-2 and B-52 bombers and deployed at high altitudes, the MOP’s innovative design features include a Global Positioning System navigation system. The MOP is approximately 20.5 feet long, with a 31.5-inch diameter.

The weapon will carry over 5,300 pounds of explosive material and will deliver more than 10 times the explosive power of other penetrators. MOP is designed to go deeper than any previously fielded penetrating weapon.

The U.S. Air Force is the only component of the DoD with the capability to deliver the most effective current penetrating weapons. There are 19 operational B-2[13] Spirit bombers and 221 F-15E[14] Strike Eagle fighter bombers to conduct the strikes against a target country's SIF complex. Additionally, there are 65 B-1 Lancer[15] and 74 B-52 Stratofortress[16] bombers all of which are currently not certified to deliver the complete inventory of nuclear or conventional penetrating weapons. With two penetrating weapons per airframe per sortie, the ability to defeat even a small to medium sized nationwide program is beyond the relative capacity of the current fleet of aircraft and the available inventory of penetrating weapons. Quite simply there are not enough airplanes or bombs to effectively do the job. With rapid dig-out capability and other measures to reconstitute previously struck targets, the U.S. has insufficient capability to destroy enough targets to kill the starfish which is typical SIF architecture. As of December 2000, the number and depths of targets were already outpacing the introduction of new penetrating weapon into the U.S. inventory. Since the following diagram was created, hundreds of new facilities have been constructed globally.

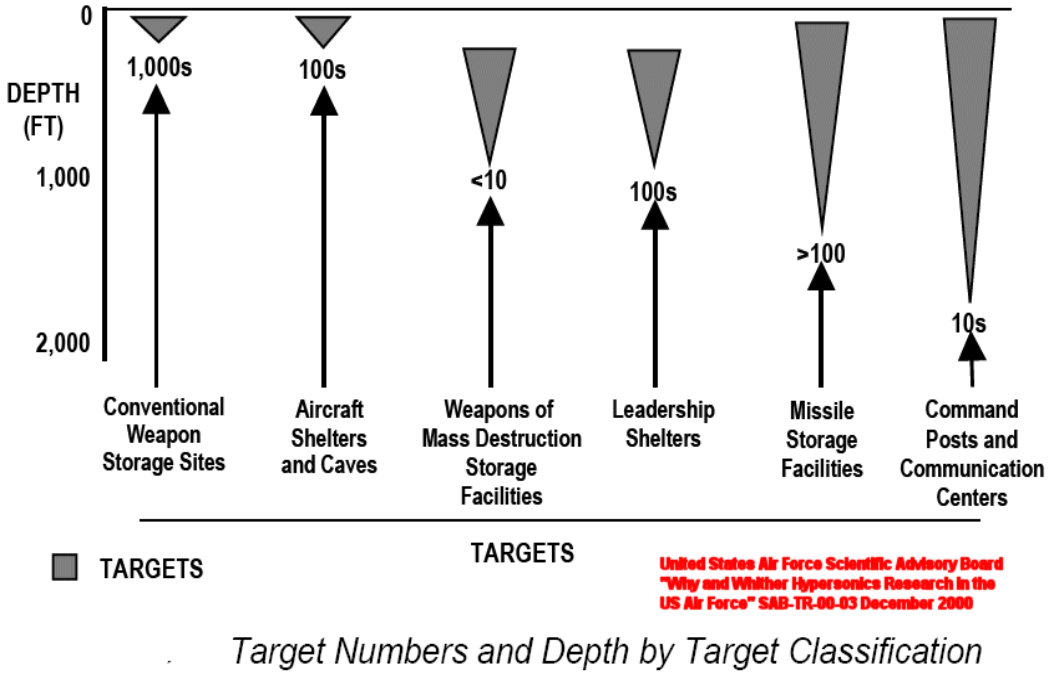

Figure 2. Target Numbers and Depth by Target Classification

Source: Dr. Ronald P. Fuchs, "Why and Whither Hypersonics Research in the U.S. Force" (U.S. Air Force Scentific Advisory Board Report, December 2000), 21.

What can the U.S. do today to hold a large, nationwide SIF complex at risk and remain below the nuclear threshold? The primary attack platform is the B-2 Spirit strategic bomber. Through progressive upgrades, the 19 operational aircraft have the ability to deliver a number of various types of penetrating munitions. The three most prominent capabilities are the 5,000-pound class, BLU-113 Penetrator, the improved BLU-122 Penetrator, and the 30,000-pound class MOP GBU-57A/B. The Spirit can carry a maximum payload of 60,000 pounds, which equates to a pair of GBU-57s or larger number of lighter weapons. The F-15E Strike Eagle is also capable of effectively delivering the BLU-113 in its laser guided, GBU-28 form and as the GPS-guided GBU-37 Global Positioning System Aided Munitions (GAM). However, this aircraft does not

have the stealth, range and payload options of the larger B-2 bomber, which limits its overall employment potential.

Unfortunately, due to the limited size of the delivery force, platform payload constraints and the limited procurement of penetrating weapons, actual capabilities are unimpressive compared to the threat they are designated to counter. The total inventory of conventional deep penetrating weapons is estimated to be several hundred (400 +/-) BLU-113 & BLU 122 Penetrators and several dozen (30 +/-) GBU-57A/B.[17] There are also approximately 3,500 of the significantly less effective one-ton, I-2000/BLU-109 penetrators in the inventory. Beginning in Iraq in 1991, these weapons have proven to be operationally ineffective against most hardened underground facilities. They are particularly ineffective against tunnels, even when skipped directly into the tunnel entrance. Faced with the dilemma of the preponderance of the inventory being inadequate against a large scale SIF network, commanders, planner and other key decision makers must be pondering the results of any campaign targeted against a large number of underground facilities.

For example, the country of Iran has at least 57 known facilities of varying hardnesses and depths[18] which have been identified as related to the country's nuclear and ballistic missile programs. It is also speculated that there are more, as yet undiscovered facilities, which serve as command and control nodes, in addition to supporting weapons of mass destruction (WMD) related infrastructure. Assuming complete availability of assets and expending the entire inventory of penetrators, the U.S. military appears to have barely adequate resources to strike the known Iranian facilities with at least two weapons per target. In all practical reality, given size and complexity

target geometry of some of the facilities, it is doubtful that the primary mission space of every target will be reached and catastrophically killed.

The MOP represents a non-nuclear capability absent from the U.S. arsenal since the late 1940s. While complete physical destruction of a UFAC may be desired, for some hard and deeply buried targets this effect is not practicable with current weapons and employment techniques. It may be possible, however, to deny or disrupt the mission or function of a facility. Functional defeat is facilitated through better data collection and intelligence preparation against the potential targets. The defeat process includes finding and identifying a facility, characterizing its function and physical layout, determining its vulnerabilities to available weapons, planning an attack, applying force, assessing damage, and, if necessary, suppressing reconstitution efforts and restriking the facility. New more lethal defeat options for HDBTs like the MOP, that can overwhelm target characterization uncertainties, are being developed and demonstrated to provide increased weapon lethality and improved penetration capability compared to previous inventory weapons. There are many who believe this weapon to be the complete answer to the SIF problem. However, given the advances in construction and mining technology, prospective SIF nations simply need to dig deeper and acquire the right technology to counter even the greatest claims of MOP potential.

Truly, in middle of the second decade of the 21st century, technology currently favors the defense. The U.S. lacks a whole-of-government approach. How must this issue be addressed?

These fortified national edifices are now networked and integrated as elemental aspects of strategic and military power. A new domain has emerged which must be

appreciated for its dynamic effect on policy, strategy and even national resolve. This emerging issue requires a paradigm shift in the current U.S. strategic and operational approach. Military emplacements have existed since man first sought shelter and safety from threats. It has been a constant struggle between the besieged and the breachers to achieve dominance. Today, depth and design favor those within the fortifications. Advanced construction and design techniques coupled with technological improvements in mining have created a perfect storm of ultrastrong fortifications located at depths unreachable to all but the most distinctive and matchless weapon systems. It is not a single adversary but rather a global problem enhanced through information sharing and parallel non-military applications.

As an issue of national security, what is the scope of the U.S. program to counter SIF? There is an unclassified program of record which attempts to establish a counter SIF agenda. The Hard and/or Deeply Buried Target Defeat Capability (HDBTDC) Program[19] is the primary military framework. However it is largely a research project which attempts to leverage existing technologies to establish a baseline. It is not the type of integrated national level program required to effectively address the SIF issue. The following two excerpts clearly highlight the programs limited goals and intentions;

> An objective of this project is to examine the existing U.S. and Allied capabilities to hold hardened, deeply buried tunnel targets at risk, thereby defining a current performance baseline. Any deficiencies will be identified and the ability of planned systems to address these deficiencies will be assessed. Finally, new technologies needed to mitigate remaining shortfalls will be evaluated as candidates for new hard target defeat acquisitions.
>
> The HTD program objective is to develop and demonstrate end-to-end capabilities for the functional defeat of hard targets, particularly tunnels, and assess developing weapon and sensor concepts against such targets. The program does not develop new sensors; it assesses existing or emerging technologies being developed by others.[20]

This program, with its limited goals and objectives pales in comparison to China and its current efforts. Of all the nations currently developing and expanding their SIF, China has the most technologically robust and aggressive construction effort. So significant is this program, that it received direct attention in the *Annual Report to Congress, Military and Security Developments Involving the People's Republic of China, 2011*. This is what the report outlined to Congress:

> PLA Underground Facilities
>
> Since the early 1950s, the PLA has employed underground facilities (UGFs) to protect and conceal its vital assets. China's strategic missile force, the Second Artillery Corps (SAC), has developed and utilized UGFs since deploying its oldest liquid-fueled missile systems and continues to utilize them to protect and conceal their newest and most modern solid-fueled mobile missiles. As early as the mid 1990's Chinese media vaguely acknowledged the existence of UGFs that support the SAC. Since December 2009, several PRC and foreign media reports offered additional insight into this obscure tunnel network, which reportedly stretches for over 5,000 km.
>
> Given China's nuclear policy of ―no first use and, until recently, it's limited ballistic missile early warning capability, Beijing had assumed it might have to absorb an initial nuclear blow prior to engaging in ―nuclear counterattack. Nuclear survivability was particularly critical given China's relatively small number of nuclear weapons and the development by potential adversaries of modern, precision munitions. In recent years, advanced construction design has allowed militaries to go deeper underground to complicate adversarial targeting.
>
> Although secrecy and ambiguity remain China's predominant approach in the nuclear realm, occasional disclosure of information on some missile-related UGFs is consistent with an effort to send strategic signals on the credibility of its limited nuclear arsenal. These public disclosures include images of tunnels, modern network-based security and control centers, and advanced camouflage measures. Categories of military facilities which make good candidates for UGFs include: command posts; communications sites; storage for important weapons and equipment; and protection for personnel.[21]

With potentially over 3,100 miles of networked tunnel and Underground Facilities (UGF) infrastructure, the sophistication and complexity of this problem is daunting. It is beyond the current non-nuclear capabilities of the U.S. arsenal in terms of number of

targets versus the number of weapons in inventory (assuming the delivery platforms can reach their targets unmolested by the advanced People's Liberation Army IADS) and the current physical limitations of the weapons themselves. Even more concerning is the advanced mining and other industrial technologies the Chinese possess and continue to pursue.

The Chinese government has openly published technology acquisition efforts. In order to drive technology access and acquisition, the Government of China publishes its technology roadmap. The document is officially known as China's *National Medium- and Long-Term Program for Science and Technology Development (2006-2020),*[22] published by the State Council in February 2006. The plan it outlines seeks to transform China into an innovation oriented society by 2020. The overall plan defines China's science and technology focus in terms of basic research, leading edge technologies, key fields and priority subjects, and major special items, all of which have military applications. This is a multifaceted long-term approach, which will rapidly advance the entire Chinese nation. The greater subtext is in relationship to its national SIF program. Specifically, China has identified several areas that have military applications as major strategic needs or science research plans requiring active government involvement and funding: material design and preparation; manufacturing in extreme environmental conditions.

The technology pursuit can be further dissected into specific applications for the design, construction and operation of an advanced underground network of command posts, communications nodes, strategic weapons systems and facilities to protect key personnel. The specific SIF related technologies targeted for development include:

Information Technology: Priorities include intelligent perception technologies, ad hoc networks, and virtual reality technologies.

New Materials: Priorities include smart materials and structures, high-temperature superconducting technologies, and highly efficient energy materials technologies.

Advanced Manufacturing: Priorities include extreme manufacturing technologies and intelligent service advanced machine tools.

Advanced Energy Technologies: Priorities include hydrogen energy and fuel cell technologies, alternative fuels, and advanced vehicle technologies.

Major Special Items: China has also identified 16 major special items for which it plans to develop or expand indigenous capabilities. These include core electronic components, high-end universal chips and operating system software, very large-scale integrated circuit manufacturing, next-generation broadband wireless mobile communications, high-grade numerically controlled machine tools, large aircraft, high-resolution satellites, manned spaceflight, and lunar exploration.

Transport Infrastructure Construction and Maintenance Technologies and Equipment: Priorities will be given to developing critical technologies and equipment with respect to rail transport, cross-bay routes, offshore deep water harbors, large airports, large bridges and tunnels, integrated 3-D traffic hubs, deep-sea oil andgas pipelines, and other sophisticated transportation infrastructure.

Efficient Transport Technologies and Equipment: Priorities will be given to research on and development of heavy duty passenger cars, large power locomotives, special heavy duty vehicles, urban rail transit systems, large high-tech ships, large oceangoing fishing boats, scientific expedition ships, and novel shipping tools, including

lower altitude multipurpose aircrafts, and high viscosity crude oil and multiphase flow pipeline transport systems.

If successfully acquired and effectively introduced, these advanced technologies with further accelerate the Chinese SIF program. The Chinese are making no effort to conceal the scope or intention of their national program. While the facilities themselves may be hidden out of military necessity, the Chinese have a published program utilizing whole of government efforts which will not only advance China economically but will also have significant military related technology strands which will significantly improve the already vast Chinese SIF network. The only present U.S. countermeasure to this developing underground architecture is to introduce a new penetrating weapon which can only be delivered by less than two dozen aircraft. This is hardly an effective counter to an extensive and growing underground strategic network.

This is not the first time a nation has constructed a complex network of fortification as part of their overall military efforts. The greatest fortification effort in history, in terms of number of facilities, and complexity of the effort within a short duration of time was Germany's effort during WW II. There will be an in-depth examination of the German effort but first fortification itself must be explored.

The Historic Issue

Fortifications are military constructions and buildings designed for defense in warfare and military bases. Humans have constructed defensive works for many thousands of years, in a variety of increasingly complex designs. The term is derived from the Latin *fortis* ("strong") and *facere* ("to make"). The word fortification can also refer to the practice of improving an area's defense with defensive works. Fortification is

usually divided into two distinct types, namely permanent fortification and field fortification (field fortification will not be addressed in detail as it is largely unrelated to the SIF concept). Permanent fortifications are erected with all the resources that a state can supply of in terms of constructive skill, advanced design methodologies, and are built of resilient materials chosen for their strength and enduring qualities.

The use of steel and concrete in the construction of fortifications became very common during the late 19th and early 20th centuries. This temporarily yielded the advantage to those within the hardened structures. However the advances in the early 20th century made large-scale, fixed fortifications obsolete in most situations. It is only the underground bunker which has endured and remains effective in providing some measure of protection from the weapons and technology of the modern battlefield. However, this was not a proven concept when Germany began to rearm in the 1930s, fortification was integral to these efforts. However, as the scope and duration of the conflict grew more intense and complex, so did the German fortification efforts. Specifically, as long-range-artillery and strategic bombing became increasingly effective so do did the requirement to protect national infrastructure and key strategic assets through fortification. By the time the conflict concluded, Germany had constructed the most extensive system of fortifications ever seen.

Although not networked in the contemporary sense, the fortification system constructed by Germany throughout the war had both unprecedented depth and sophistication. From prefabricated tactical emplacements to extremely elaborate V2 ballistic missile fixed launch complexes, there was no type of fortification the German military industrial complex did not utilize. The irony of this massive and intricate military

architectural complex was that if the war would have been fought as originally envisioned, there would have been no need for such a massive and labor intensive construction effort. In the end, what was conceived prewar was a mere fraction of what was ultimately built.

Wartime necessity compelled the Germans to dramatically expand their construction efforts by orders of magnitude and develop construction projects heretofore unimagined. Beyond the futuristic V-weapon sites, the Germans built the virtually impregnable U-boat pens constructed along the Atlantic Coast and the ever expanding Atlantic Wall, fortified English Chanel Islands and subterranean factories and other essential wartime production facilities were also forced underground and finally a diverse series of leadership bunkers for survivable command and control.

An interesting point to note is that the submarine pens and other fortifications had been built in 1940 and 1941, when the Germans had some level of air supremacy and could defeat air attacks. By 1942 this advantage had been lost to the U.S. Army Air Force and a greatly expanded Royal Air Force. The example of Germany provides insights which are instructive even today. The most extensive construction occurs when there is the least amount of pressure. The pressure does not necessarily need to be exclusively of a military nature. Diplomatic, information control and economic influences can be brought to bear which can apply significant amounts of pressure and have a cumulative effect on any mass construction effort.

Another element which ties directly to the whole of government approach is the cultural fabric of the U.S. and its ability to rapidly field innovative technical solutions. This also has a historic parallel. During the Second World War, to address the continued

hardening of German military and industrial infrastructure, innovative solutions were required. One such solution was born in the mind of British weapon designer and engineer Barnes Wallis. He conceived the largest conventional bombs ever used in combat. So complex was the problem of destroying German fortifications, that at one point Wallis had conceptualized a requirement for a bomb weighing 70,000 pounds, dropped from 45,000 feet. When it was obvious that this was beyond technical reach, Wallis conceptualized an earth penetrating bomb, which when detonated, produced an earthquake like effect in close proximity to its target leading to the target structure collapsing.

The physics behind this approach is relatively simple. An explosion in air or on the surface does not transfer much energy into a solid. Due to the lack of accuracy of bombing in the face of anti-aircraft defenses, the primary tactic by air forces employed was area bombardment, dropping large numbers of bombs so that it would be likely that the target was hit. Although a direct hit from a light bomb would destroy an unprotected target, it was comparatively easy to armor ground targets with many yards of concrete, and thus rendering critical installations such as bunkers essentially bombproof. Wallis' idea was to drop an extremely heavy bomb with a hard armored tip at supersonic speed so that it penetrated the ground - an effect comparable to a 10-ton bullet being fired straight down. It was then set to explode underground, ideally to the side of, or underneath a hardened target; the resulting shock wave would produce the equivalent of a miniature earthquake, destroying any nearby structures such as dams, railways, viaducts, etc. Any concrete reinforcement of the target would likely serve to enclose the force better. Wallis also argued that, if the bomb penetrated deep enough, the explosion would not breach the

surface of the ground and thus produce an underground cavern (known as a camouflet) [23] which would remove the structure's underground support, thus causing it to collapse. The process was graphically described as a "trapdoor effect" or "hangman's drop." Wallis' ideas were shown to be superbly successful. Once he effectively made his argument and was able to garner support, Barnes Wallis designed two bombs based on the "earthquake bomb concept." The first to see action was the 6-ton, 12,000-pound "Tallboy" bomb. This weapon was followed by the 11-ton, 22,000-pound "Grand Slam" bomb. The earthquake bombs were used to good effect against the hardest German facilities, sink the German Battleship Tirpitz and to attack many other targets which had been impossible to damage previously.

In the end, it was a combination of target specific aerial bombardment and neutralization through bypass which were the methodologies employed by the Allies to counter the vast German defensive network. It was only the most critical target which enjoyed the attention of the large specialized ordinance. The Allies simply did not have the resources to devote in order to inflict catastrophic destruction against the German fortifications. However, Wallis' bombs were a true spark of imaginative thought which led to an innovative solution.

Likewise, during the 1991 air campaign over Iraq, the GBU-28 laser guided bomb was developed, built, tested, and used in combat within a 17-day period. The deepest Iraqi bunkers were secure from the best penetrating bomb, the GBU-24A/B, with the I-2000 warhead. Coalition leaders required the capability to destroy vital command and control facilities beyond the GBU-24's reach. The GBU-28 was not even conceptualized when Kuwait was invaded in 1990. The perception was that the existing the I-2000/

BLU-109 penetrators could hold the entire underground theater target set at risk. Using surplus 8-inch artillery tubes, the new bomb was fabricated starting on 1 February, 1991. The first two units were delivered to the U.S. Air Forc by 17 February 1991. Following acceptance trials and integration, the first two operational bombs were delivered to the theater on 27 February 1991.

Despite rapid introduction of limited capabilities, for decades the primary means of addressing the issue of subterranean fortification was the widespread use of nuclear weapons. This narrow focus has limiting effects on other tools and mechanisms which could have influenced the U.S. strategic approach to the SIF issue. Unfortunately, since nuclear weapons were the only probable option, noone looked beyond their capability to solve the problem. The Soviets were astute students of German construction and fortification efforts. They built and continue to build a similarly vast network of hardened facilities, which span the Eurasian landmass. However, unlike the Germans, they faced the prospect of having to defend against nuclear weapons. These weapons are available by the thousands. As targets became harder to defeat, higher weapon yields and greater accuracy permitted the continued targeting of underground facilities.

Cold War Nuclear Options

For the U.S., the development and mass production of the high yield (>4.5 megatons) hydrogen bombs provided the confidence to hold any target at risk anywhere on the planet. The power of these weapons was not intended to destroy cities but rather it fulfilled the need to hold the hardest facilities at risk. The WW II era block buster bombs: Tallboy (5-ton), Grand Slam (10-ton) and T-12 (22-ton) were minuscule weapons compared to what replaced them. With the advent of nuclear bombs, destructive force

grew by orders of magnitude. The first crude nuclear weapons had yields equal to tens of thousands of tons of explosive force. The yield of the device which detonated over Hiroshima is estimated to be equal to roughly 15,000 tons or 15 kilotons. This is a low yield weapon by today's standards. The highest yield nuclear weapon ever deployed by the U.S. was the Mk41 whose yield was 25 megatons (MT) or the equivalent of 25 million tons of high explosive. The Soviets tested a device in 1961 designed by Andrei Sakharov known as the Tsar Bomba (Russian: *Царь-бомба*; "Emperor Bomb"). This was the nickname for the AN602 hydrogen bomb, the most powerful nuclear weapon ever detonated and its 30 October 1961 test remains the most powerful artificial explosion in human history. The yield was 58 MT. This was just over half of the designed yield of 100MT.[24] Despite its construction and testing, a weapon of this power had no practical application. With improved accuracy, smaller yet still high yield weapon could achieve the same effect as near misses with much larger weapons.

The Mark 17 and Mark 24 weapons were the first mass-produced hydrogen bombs deployed by the U.S. They weighed 21 tons and not coincidentally the devices were very similar in size and basic shape to the T-12 Cloudmaker, penetrating bomb. As a matter of fact, the same handling equipment was utilized to load the B-36s when the weapons were introduced into service. Reported yields for the Mk-17 and Mk-24 range from 10 MT to 15 MT.[25] U.S. high yield nuclear bombs culminated with the 9MT, B53. It was the last of the big bombs to enter the U.S. nuclear stockpile. The B53 entered production in 1962 and was built through June 1965 with about 340 bombs being produced. From the outset, the bomb was intended as a bunker buster weapon, using a surface blast after laydown deployment to transmit a shock wave through the earth to

collapse its target. Attacks against the Soviet deep underground leadership shelters in the Chekhov/Sharapovo area south of Moscow envisaged multiple B53s/W53s exploding at ground level.[26] The B53 was to be retired in the 1980s, but 50 units remained in the active stockpile even after the deployment of the B61-11 Earth Penetrating (Nuclear) Weapon (EPW) in 1997. The bomb's unique capabilities led to its retention in the stockpile until October 2011.[27]

The Current Nuclear Option

B61 Mod 11 is an intermediate yield strategic and tactical nuclear weapon. The B61 Mod 11 has a much lower variable yield but actually penetrates the surface to deliver much more of its explosive energy into the ground. This technique is known as ground coupling. Since the weapon actually detonates below the surface, not resting on top, there is a much greater physical energy transfer which achieves the same level of energy transfer at a significantly lower thermonuclear yield.[28] The lower yield of an Earth Pentrator Weapon (EPW) greatly reduces airblast, radioactive fallout, and other effects on the earth's surface. To withstand the immense force of striking and penetrating the earth before detonating, an EPW needs a strong case and may require internal strengthening. The current EPW, the B61-11, was made by modifying an existing bomb in ways that did not require nuclear testing. The weapon has significant operational limitations: "The Nuclear Posture Review," which the George W. Bush Administration prepared in response to a congressional mandate and briefed to Congress in January 2002, stated, that the B61-11 "has a very limited ground penetration capability" and "cannot survive penetration into many types of terrain in which hardened underground facilities are located." The Mod 11 weighs about 1,200 pounds. Current estimates are that

150 Mod 11 bombs have been produced, their warheads converted from Mod 7 bombs. At present, the primary carrier for the B61 Mod 11 is the B-2 Spirit. Now, with precise accuracy, a sub-Megaton weapon has replaced the last of the very high yield weapons in the ultimate bunker buster role.

The Next Evolution: Robust Nuclear Earth Penetrator (RNEP)

During the first term of President George W. Bush's Administration, the "Nuclear Posture Review" considered nuclear EPWs, which would burrow tens of feet into the ground before detonating to improve their ability to destroy buried facilities. The FY2003 Department of Energy. (DOE) budget request included $15 million to begin a study on a RNEP. The request led to congressional and public debate because EPWs involve such policy issues as circumstances under which the U.S. would use nuclear weapons, military value of EPWs, and nonproliferation deeply buried structures can be built to withstand an attack using conventional munitions. They may protect strategic military facilities, such as for sheltering leaders, producing biological agents, and storing nuclear weapons. The Defense Intelligence Agency estimates that over 1,400 known or suspected strategic underground facilities exist worldwide. Some may be vulnerable only to EPWs. Special operations forces or precision-guided conventional bombs might "defeat" deeply buried structures by attacking power supplies, ventilation systems, and exits. The only way to "destroy" them is with a strong shock wave that travels through the ground. Stephen Younger, then Associate Laboratory Director for Nuclear Weapons, Los Alamos National Laboratory, wrote "Some very hard targets require high yield to destroy them. No application of conventional explosives or even lower-yield nuclear explosives will destroy such targets, which might include hardened structures buried beneath hundreds of

feet of earth or rock."[29] Indeed, "Superhard" targets, such as those found under certain Russian mountains, may not be able to be defeated reliably by even multiple high-yield nuclear weapon strikes."[30]

The George W. Bush Administration requested $15 million for FY2003 to study an improved penetrator, the RNEP. Two technical points are worth noting. First, RNEP is not conceived as a low-yield weapon. John Gordon, then Director of the National Nuclear Security Administration, testified that the emphasis is on "a more standard yield system called an enhanced penetrator . . . there's no design work going on low-yield nuclear weapons."[31] While an EPW can destroy a buried target with less yield than a surface burst weapon, increasing the yield increases the radius of damage. Second, although EPWs would reduce fallout, they would not eliminate it. It should also be noted that only a small percentage of buried facilities in adversary nations could be defeated "only" by RNEP. Some undergrounds are vulnerable to nonnuclear weapons. Likewise, some may be vulnerable to the B61-11 and still others may be invulnerable even to a potential RNEP. Undoubtedly, some facilities remain undetected, and there may be insufficient intelligence on others that may inhibit targeting. These points clearly establish that the narrow focus of the current military kinetic options is at best extremely limited solutions to a very complex problem.

The narrow focus of a military only option has garnered few effective results. As nuclear weapons become less likely to be employed due to concerns over collateral effects and conventional weapons are nearing their physiological limits, based on current delivery platforms, other alternatives must be pursued. Although acknowledged as a National Security priority indirectly with various technology development programs,

nowhere in any of the official policy documents is there any attempt to approach the problem through a comprehensive or holistic approach. Such a methodology would couple DIME efforts.

If SIF were to become a declared strategic issue for the U.S., other elements of national power could project their influence against the problem as well. For example, diplomacy has proven to be one of the greatest arbitrators in expensive arms races. The obvious question is can the U.S. ask both friendly and hostile nations to join it in not creating fortifications beneath the surface of the earth? The answer goes back to the arms control efforts of the 20th century. The 1920s Washington Naval Conference was a watershed event in that, for the first time, restrictions on the size and capabilities of military forces over a set period of time was mutually agreed upon by all internationally concerned parties. The crucial linkage to SIF was Article XIX,[32] which is sometimes referred to as the "Fortification Clause." Article XIX prohibited Britain, Japan and the U.S. from constructing any fortifications or new naval bases in the Pacific. It specifically provided that "no new fortifications or naval bases shall be established in the territories and possessions specified; that no measures shall be taken to increase the existing naval facilities for the repair and maintenance of naval forces, and that no increase shall be made in the coast defenses of the territories and possessions above specified." Never before had any group of nations mutually agreed not to passively defend their territories through fortification. Precedent is set and can now be utilized as a diplomatic tool to counter SIF expansion.

Beyond the Washington Naval Treaty, during the late 1960s and through the end of the Cold War were series of strategic arms limitation and reduction treaties between

the U.S. and Russia (previously the Soviet Union). These protocols limited everything from nuclear weapons tests to the size, composition, deployment configurations and capabilities of each side's nuclear arsenals. Strategic Offensive Reductions Treaty (SORT) was one in a long line of treaties and negotiations on mutual nuclear disarmament between Russia (and its predecessor, the Soviet Union) and the U.S., which includes the Partial Nuclear Test Ban Treaty (1963), the NPT (1968), SALT I (1969–1972), the ABM Treaty (1972), SALT II (1972–1979), the Intermediate-Rangle Nuclear Forces Treaty (1987), START I (1991), START II (1993), START III, SORT (2002), and New START (2010).

The Space Weapons Treaty or better known as the Outer Space Treaty, (formally the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies)[33] is another critical treaty which has broad applications to any counter-SIF strategy due its shaping conditions related to the weaponization of space. Among its principles, it bars states parties to the treaty from placing nuclear weapons or any other weapons of mass destruction in orbit of Earth, installing them on the Moon or any other celestial body, or to otherwise station them in outer space. It exclusively limits the use of the Moon and other celestial bodies to peaceful purposes and expressly prohibits their use for testing weapons of any kind, conducting military maneuvers, or establishing military bases, installations, and fortifications (ArticleIV). However, the treaty does not prohibit the placement of conventional weapons in orbit. The treaty also states that the exploration of outer space shall be done to benefit all countries and shall be free for exploration and use by all the States.

Finally, the Treaty on the Non-Proliferation of Nuclear Weapons, commonly known as the Non-Proliferation Treaty or NPT,[34] is a landmark international treaty whose objective is to prevent the spread of nuclear weapons and weapons technology, to promote cooperation in the peaceful uses of nuclear energy and to further the goal of achieving nuclear disarmament and general and complete disarmament. Within that general concept, it may be possible to frame fortification as inherently destabilizing and therefore a threat to the peace the NPT seeks to establish. However, utilizing the current limited direct interpretation of the NPT, there is very little latitude. But, if new language were adopted or even broader interpretation accepted, this could compel signatory nations to open UFACs to inspection and certify tunneling technology is utilized only for non-military purposes. Such revised terms could be a forcing function to inhibit some nations from creating UFACs to support nuclear related programs.

If this interpretation were pursued, nations utilizing SIF infrastructure would have to either open facilities to inspection or face international pressure such as sanctions or even threat of a military response such as the is the case today with nations suspected to be in violation of the NPT. The whole of DIME construct must initially be supported by an internationally recognized legal framework. Without that basis, no restrictions can be applied to prevent the expansion of the SIF programs and the activities they conceal and protect them. The provocative aspects of SIF can be a compelling factor in changes to international law and legal protocol. The 20th century has numerous examples of diplomatic efforts preventing or delaying conflict.

The most obvious current obstacle to success is the proliferation dual-use technological enablers. This is particularly true of technology from the global mining

industry. With increased global demand for gold, diamonds and rare earth elements, advances in mining technology are opening previously inaccessible depths to exploitation. However, there is an opportunity through proprietary rights and leasing of technology to prevent its use in illicit activities. During the Cold War, the West enjoyed certain technical and industrial advantages over the Soviets. There were mechanisms established to control the transfer of sensitive technology which could provide a military advantage. The best example is the computer control multi-axis milling technology obtained by the Soviets in the early 1980s. This was pioneered in the U.S. and had direct military application in creating advanced submarine propeller blades, which for years, provided an acoustic advantage to U.S. and United Kingdom submarines. In 1981, the Toshiba Machine Company and Kongsberg Vaapenfabrik began selling advanced milling machinery and accompanying numerical control equipment to the Soviet Union in violation of the regulations of the Coordinating Committee for Multilateral Export Controls (Cocom).[35] The illegal shipments of state-of-the-art equipment to the Soviet Union by Toshiba and Kongsberg served to seriously undermine Western national and international security. This incident sharply illustrates the inherent weaknesses in the effectiveness of multilateral export controls. This is also a very clear example of how industrial technology transfers can alter the military balance. The consequences of the Toshiba technology transfer were huge. Soviet submarine quieting surged forward and achieved a level of quietness not anticipated for more than a decade. Today, following the end of the Cold War the level of knowledge and technology control is significantly reduced. Controlled access to advanced technology is almost impossible without concerted international effort. Again, diplomacy has to be the lead agent to protect

intellectual properly, particularly that which has military industrial potential. Ultimately, all factors are linked economically. For the right price, most technology can be acquired by any actor, nation or corporation with sufficient financial resources and ample patience.

The only viable solution to the overall SIF problem is a national application of DIME efforts. Such an effort cannot be undertaken without understanding the financial aspects of the requirement. The U.S. is facing huge economic burdens from debt and poor financial performance. Is there political will to pursue a large-scale national effort? The answer lies with the perception of the threat and the national will to undertake a costly program perhaps on the scale of the Manhattan Project adjusted for current rates.

Can the U.S. afford not to pursue dominance within this domain? Most citizens understand the relevance of the cyber domain because it touches everyone's lives daily. Ground, sea and air are obvious military domains. The subtera/SIF domain is somewhat amorphous to the technically uneducated. National level focus will require national level understanding of the problem and leadership to lead the elements of power both internal and external to the U.S. in order to achieve the desired affects. It is possible, but significant changes will need to occur in the diplomatic, military and economic sectors of the U.S. and our global partners to achieve dominance within the domain in a manner that expands beyond military capability alone. Ultimately, control of the domain will be through military means with the other factors impacting the peripheries. However, the whole of DIME effort will be a significant enabler in achieving dominance over the SIF domain.

Conclusions

1. SIF is a new and as yet, not formally recognized warfare domain.
2. The U.S. has not achieved dominance in this domain.
3. The U.S. has no national consensus or counter-SIF stratagem.
4. Within potential adversary nations, there are 2,000 or more identified strategically important facilities sheltered inside of underground complexes. The U.S. arsenal has insufficient conventional penetrator weapons or delivery platforms to service these known targets.
5. Many of the strategically most important targets are beyond the reach of conventional penetrating weapons and can be held at risk of destruction only with nuclear weapons. Many deepest buried targets can only be held at risk of destruction through the use of multiple nuclear weapons. There are some facilities beyond the reach of even multiple nuclear weapon strikes, rendering them invulnerable to destruction.
6. Nuclear weapons are increasingly weapons of deterrence and last resort. In the Post-Cold War Era, the detonation properties and collateral effects have significantly reduced the likelihood of their employment.
7. Diplomacy is a proven arms control mechanism. Given the appropriate approach, it may be an effective means to slow the global expansion of SIF.
8. China has the largest national SIF complex. It has an open and long-term effort to pursue advanced technologies in order to improve and expand its already massive national underground network.

9. Historically, even with unconstrained resources, there had never been an exclusive counterfortification campaign; counter-SIF efforts have always been a limited part of a broader military campaign.
10. Advanced mining and construction technologies have dual-use military applications and are largely uncontrolled in today's open information environment.

Chapter 5 will chart potential solutions to the critical issues identified throughout this chapter. Time and technology continue to advance. Without cogent and disciplined approaches, none of the highlighted issues will be effectively addressed. The subterranean environment will be controlled by those willing to devote resources and intellectual capital to achieve domain awareness and control.

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CHAPTER 5

CONCLUSIONS

> It is not probable that war will ever absolutely cease until science discovers some destroying force so simple in its administration, so horrible in its effects, that all art, all gallantry, will be at an end, and battles will be massacres which the feelings of mankind will be unable to endure.
>
> — W. Winwood Reade, *The Martyrdom of Man*

Today, there is no disputing that depth and design favor those within the fortifications. This chapter will examine potential government-wide, holistic solutions to the subterranean fortification dilemma. Advanced construction and design techniques, when coupled with technological improvements in mining, have created an environment of super strong fortifications located at depths virtually unreachable to all weapon systems. Even more challenging is that fact that it is not a single adversary but rather a global problem enhanced through information sharing and parallel non-military applications. The failure of the U.S. to apply all elements of national power (DIME) as part of a cohesive approach means that those nations willing to invest in the development of SIF can directly challenge the U.S. and it allies from unassailable locations.

Historically, the U.S. has relied upon space, air, naval and (to lesser degree) land power to achieve military dominance. Unfortunately, despite relative control of the air, space, sea and significant influence over the surface domain, the U.S. has little ability to influence the subterranean domain. U.S. military advantages are muted in soil, rock and reinforced concrete. With limited numbers of delivery platforms and only several hundred marginally effective penetrating weapons, the subterranean domain is open for contest by any nation with willingness to dig deep enough and fortify strong enough.

The primary question is will the U.S. pursue dominance within the SIF domain or choose to accept there are areas beyond its influence? If there is no demand or desire to pursue control over the underground domain, then it is likely the existing advantages held by those choosing to dig and fortify will only expand. Adversaries will place their sources of strength and power deeper and increasingly beyond the reach of U.S. power and influence. Due to the associated risk of ceding the initiative on the subterranean domain, it is most probable the government of the U.S. will view that it is in its national security interests to acquire the ability to hold underground facilities and hardened targets at risk. Once this option is selected, there must be a unified, whole of government approach. From the highest echelons of governance, the end state must be defined and the appropriate ways and means focused to achieve the desired solution.

SIF must become a declared strategic issue for the U.S. Only through a dogmatic national policy commitment can the other elements of national power be brought to bear against the SIF issue. The imperative now, is for the U.S. government to commit itself to develop a robust capability to hold at risk the deepest targets from a full spectrum of delivery platforms. Once SIF domain dominance becomes a declared policy issue, a unified approach across all governmental agencies becomes possible. With the interagency united in focus against SIF, all elements of the DIME can be employed.

If SIF is accepted as a new domain and strategic imperative, then actions must be undertaken to first define the domain, using language common across all involved agencies. The agencies would then have their apportioned role, utilizing the elements of power (DIME), to establish awareness and begin seeking solutions. Once the whole of the U.S. government is united behind the effort, further questions will be evoked. First

and foremost, does the U.S. actually need to achieve active dominance within the Subterranean Domain? If so, using the entire governmental enterprise, what tools are available to address the issue? Are there underdeveloped technologies or conceptual methods to achieve the desired level of dominance through non-kinetic bombardment approaches? Do diplomacy and information management have sufficient influence to provide viable non-military options? If the required technologies are currently unavailable, what is the size and scale of the research and development project required to field solutions to the problem? Is this an affordable option given current budget constraints?

This will be no small effort. In all actuality, it could likely be the greatest technological initiative since the Manhattan Project or the Space Program. In ideal circumstances, the United States should be able to destroy the hardest and deepest buried targets on the planet. To achieve this end, new sensors and weapon technologies must be developed which will allow the detection, accurate characterization and ultimate demolition of any current or conceptualized facilities. Theoretically, adversaries would have no place on or under the surface of the earth immune from the reach of the U.S.

No nation has ever pursued such a singularly focused warfare domain control effort. Instead of a focused approached, most military powers have been broad in their approaches to enhancing capabilities. During WW II, there was a brief period of virtually limitless weapon development opportunities. This limitless environment spawned nuclear weapons. It was also during this time that the world's most extensive network of SIF actively challenged through warfare and combat. The Germans in WW II utilized every conceivable technology and construction technique to secure their captured possessions

and defend against Allied assaults. The Allies, through innovative technical approaches, brute force and maneuver subdued only a small portion of the German fortified network. It proved more efficient to bypass and neutralize with isolation rather than direct efforts to breach and demolish. For example, only a small portion of the Normandy segment of the Atlantic Wall was physically breached. The portion selected for assault was the relatively shallow in comparison to those of Pas de Calais, and other obvious landing beaches. The V-weapon sites and U-boat pens were bombed with specialized penetrating and blast weapons. However, given the size and scope of the overall Allied bombing campaign in Europe, these strikes constituted less than one percent of all sorties flown during that effort. The *Strategic Bombing Survey* reported that, "in the attack by Allied air power, almost 2,700,000 tons of bombs were dropped; more than 1,440,000 bomber sorties and 2,680,000 fighter sorties were flown."[1]

Despite applying the best technology of the time, innovation and the most creative efforts possible, there was never a truly holistic approach to defeat the German SIF network. Fundamentally, it was never viewed as an issue in isolation. German SIF was operationally addressed as a component of broader military necessity. It was dealt with when circumstances demanded so. However, because the war was being fought as a total war, on a multitude of levels (air, sea, land, and production) and theaters (European, Pacific, Mediterranean Sea, South Asia etc.) there was never the prioritized demand to focus sufficient resources in a truly holistic approach to solving this singular technical issue. Usually, existing resources were applied. Occasionally, unique solutions, such as Wallis' special bombs were developed, but, this was the exception, rather than the rule with regards to dealing with fortified facilities and obstacles.

Could this be the case again today? Can the U.S. center broad national energies to achieve domain control without a complete mobilization of the military industrial complex?

A nation's power and influence can be effectively summarized within the DIME acronym: Diplomatic, Information, Military and Economic. How a nation chooses to spend its DIME is subject to political judgments, financial conditions, population, industrial capacity, natural resources and war making capabilities. No two countries have the same potential or priorities. It is truly an individual characteristic on the international stage. Since the end of the Cold War, the U.S. has enjoyed unparalleled military dominance. Although mired in the wars in Iraq and Afghanistan, neither conflict taxed U.S. military power to its kinetic limits. If anything, the fear of collateral damage in these insurgent conflicts has subdued the killing power and level of force applied to targets within the battle space. This fact lies in stark contrast to the requirements of dealing with HDBTs. In this particular circumstance, the U.S.' ability to kill preferred targets is inadequate. Based on current trends, the conditions are progressively degrading to the point where there will be targets beyond the reach of even the specialized weapons of the U.S. nuclear arsenal.

Today, the U.S. government only applies the military element of the DIME to address the SIF issue. Even within the military, efforts are limited by constrained budgets and other higher priority issues. What is being missed at the national policy level is the fact that any failure in this particular arena will have strategic, geopolitical consequences far beyond what most decision makers perceive. How can this imbalance be redressed and active dominance within the subterranean domain be achieved?

The U.S. must address the problem from all aspects simultaneously. It must utilize all elements of its national DIME to achieve active control over the SIF domain. Returning to the concept that SIF is like a starfish, current the U.S. military options only allow, at best, for several legs to be damaged, preserving the rest of the organism. What must be done to achieve ascendancy against a starfish is to inflict sufficient damage across its complete physiology, from which there is no recovery. Additionally, there must be active protocols to prevent the starfish from replicating either again locally or in another location, perhaps even in a mutated form. This option holds out more promise for success in this endeavor.

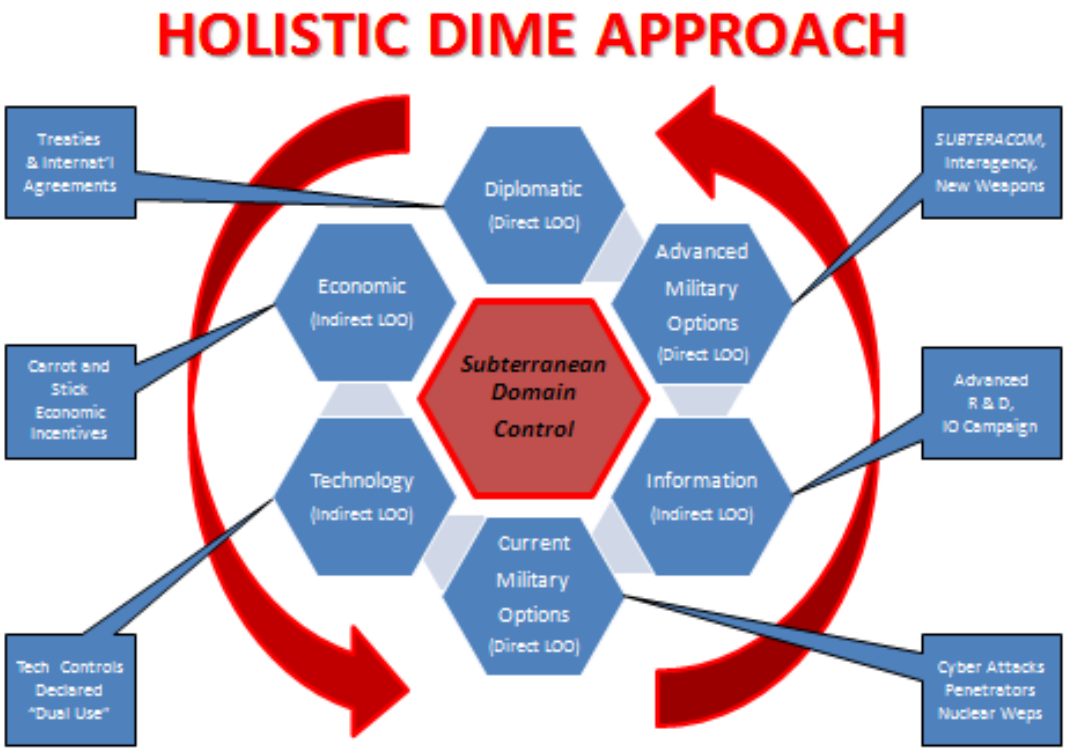
HOLISTIC DIME APPROACH
Treaties & Internat'l Agreements
Carrot and Stick Economic Incentives
Tech Controls Declared "Dual Use"
Diplomatic (Direct LOO)
Economic (Indirect LOO)
Technology (Indirect LOO)
Current Military Options (Direct LOO)
Subterranean Domain Control
Advanced Military Options (Direct LOO)
Information (Indirect LOO)
SUBTERACOM, Interagency, New Weapons
Advanced R & D, IO Campaign
Cyber Attacks Penetrators Nuclear Weps

Figure 3. Holistic DIME Approach

Source: Created by author.

As previously outlined, once the whole of government collectively works to address an issue, solutions can flow rapidly. When the national security strategy and associated core documents reflect the dangers associated with the worldwide expansion of SIF, it will spawn a national strategy. The prerequisites for a national counter-SIF strategy can be subdivided into two primary lines of effort. The Direct Lines of Effort are composed of diplomatic endeavors and international arrangements coupled with current military options and the pursuit of advanced military options. The Indirect Lines of Effort are knowledge management, technology control and economic leverage. Each of these elemental factors will be addressed in order to build understanding on why only a unified, national level approach will achieve the desired end state.

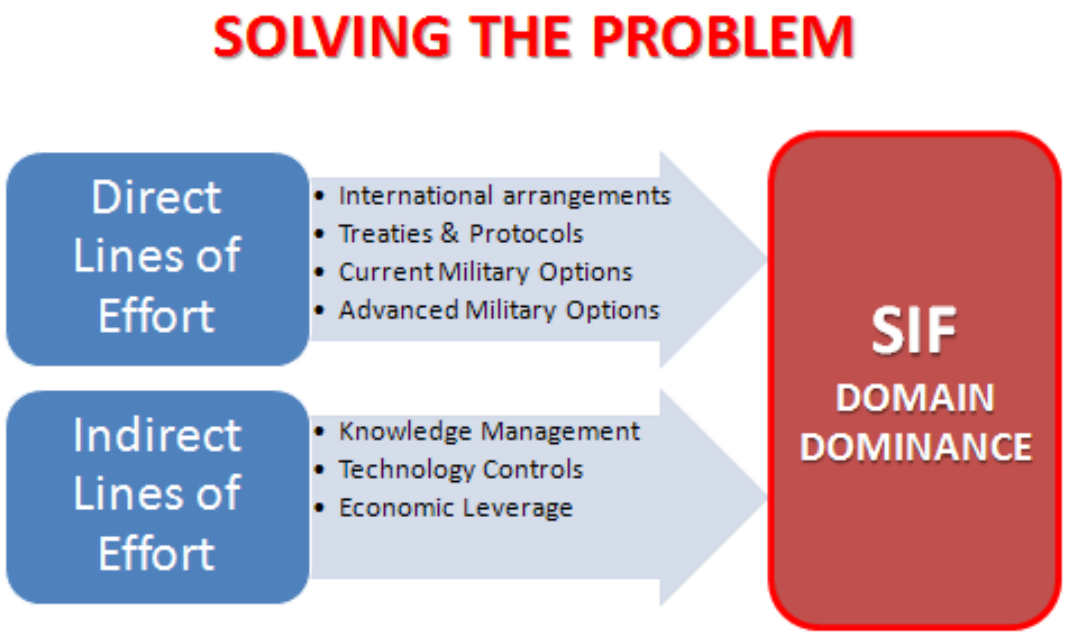

Figure 4. Solving the Problem

Source: Created by author.

The overall SIF problem is not exclusively military in nature. While the military option may be the dominate solution, it is not the exclusive answer to the question of addressing SIF dominance. The Direct Lines of Effort contain four components. First, utilizing the spectrum of diplomatic tools, cooperative relationships and internationally recognized legal frameworks and protocols, the U.S. must establish the idea of SIF as a global destabilizing issue. First, the core national security documents (*United States National Security Strategy*[2] *The National Military Strategy of the United States of America, 2011,*[3] the *National Defense Strategy*[4] and the *Quadrennial Defense Review Report*)[5] must officially recognize the issue as a threat to U.S. national security. Secondly, as sign of importance and priority, the senior members of the National Command Authority (President of the U.S. and Secretary of Defense) must educate the Legislative Branch and the American population as to the significance of the issue. Once this is achieved, the same efforts must be undertaken through the diplomatic community. U.S. diplomats must generate discussion and promote the issue as one of international concern. Once these engagements have been successfully undertaken, new and or revised international counterproliferation and arms control protocols can be introduced.

In order for the U.S. to reach the diplomatic high ground, it must lead through example. It must be willing to subject itself to the same inspection protocols, technology control and international oversight it seeks to have elsewhere in the world. This would not be unprecedented, as many of the active arms control agreements already possess intrusive inspection regimes. Likewise, the hardness of known U.S. underground facilities has not been significantly upgraded since the end of the Cold War. Thus, the U.S. gains diplomatically while its own SIF program remains unchanged. Success within

this line of effort requires a blend of tact, education, openness and elegant diplomacy. Ultimately, the desired end state is to compel nations not to construct or enhance their passive means of self-defense. This is absolutely the most essential element of the overall holistic DIME approach. It creates the foundation of legitimacy on which all other aspects will be based.

As outlined throughout this work, the current military options are limited and insufficient in isolation to address SIF on the larger scale. Within the limits of existing known capabilities and potential near horizon capabilities, what efforts can be pursued to expand military solutions to the SIF problem? The initial obvious answer is expanding the inventory of penetrators and delivery platforms. However, this only addresses one symptom of the overall issue. If the highest levels of government recognize the problem, the military will adjust its approach in unison. First, there must be organizational infrastructure to lead any DoD effort. In 2009, the USCYBERCOM was activated as a subunified command subordinate to U.S. Strategic Command.

> USCYBERCOM plans, coordinates, integrates, synchronizes and conducts activities to: direct the operations and defense of specified Department of Defense information networks and; prepare to, and when directed, conduct full spectrum military cyberspace operations in order to enable actions in all domains, ensure US/Allied freedom of action in cyberspace and deny the same to our adversaries.[6]

If SIF were to be fully recognized as an entirely new warfare domain, then a similar, subunified command oriented against the subsurface environment could be established: USSUBTERACOM. If this mission command architecture could be established, it would also be assumed that the DoD, Joint Requirements Oversight Council (JROC) would pursue the ability to hold underground facilities at risk as a standing joint requirement. Each service must, as part of its Joint Mission Essential Task

List (JMETL) have the ability to efficaciously attack a large number of the deep underground facilities. The capacities of carrier-based aircraft, submarines, surface ships and the surface-to-surface missile capabilities of the Army and Marine Corps would be expanded to include a counter-HDBT means. This undertaking would augment the current capabilities of Air Force penetrating weapons.

Unfortunately, even this enhanced operational means will still be inadequate to address the full range of targets. For the hardest and deepest targets, additional means are still required that remain unmet by even the current nuclear penetrators in the inventory. Another unaddressed critical aperture in any capability to hold SIF targets at risk is the inadequate current means of accurate target identification and characterization. Existing intelligence, surveillance and reconnaissance (ISR) sensors have no earth penetration capabilities. Imagery, speculative engineering and design concepts can provide insight but are truly limited in overall effectiveness. Without suitable sensors to fix target locations and substantiate configurations, the limited inventory of penetrators becomes even more problematic. Given the combination of all of these critical factors, the current SIF defeat options have reached the limits of what can be achieved without significant alterations to capability, inventory and policy instruments.

In any future effort to counter SIF, military technology and capabilities will be the ultimate driver. Given an unrestricted menu of capabilities, there are several requirements which must be followed. First and foremost is the absolute need to improve facility identification and characterization. This technology would allow underground facilities to be rapidly located and the dynamics of the overburden (rock mechanics) correctly assessed. Once the underground facility has been precisely characterized, the next step is

its neutralization. Within this requirement there are three potential options: first, an advanced Nuclear Earth Penetrator; second, submarine or surface launched kinetic penetrators;and finally, space-based terrestrial bombardment. The three target demolition options all have some type of penalty associated with their cost, development or employment. All have significant potential but all also have certain drawbacks which could prohibit them from being deployed and utilized. However, they do represent the ultimate Direct Line of Effort in countering SIF.

The Indirect Lines of Effort would require a more discrete and elegant approach. The key element of this line is knowledge management and technology control. Knowledge management is the control of the flow of information and the shaping of the perceptions and understanding of the knowledge. Some would categorize this as propaganda and disinformation. It is not. It is public displays of capabilities witnessed by very high-level government officials. It is the controlled releases of previously classified capabilities and other information tools to deter potential adversaries from constructing underground infrastructure. Through creating the idea that fortifying is wasted effort, it has its own causative counter-SIF effect.

The final DIME factor is economic power and leverage. This was one of the key elements of victory during the Cold War. It was an elegant controlled approach to limiting the rate of adversary economic development. The effect was inhibited economic growth and performance. Unfortunately, the world is significantly different today. Instead of the planned and isolated economic systems of the Soviet Block, the primary SIF challengers enjoy largely free markets and, or in the case of China, are verging on the becoming the world’s largest, most dynamic economy. The economic tools include

control of intellectual property. There needs to be negative consequences for violations of trade agreements and reverse engineering and production of patented technologies. The same export controls used to prohibit sales of weapons systems and related technologies can be applied to dual-use advanced mining technology. Similarly, the advanced rapid tunneling and excavation equipment could be produced and yet controlled. It could be maintained for use in rescues and other managed situations. Maintaining positive control over the advanced mining technology would impede its use in SIF related activities. Undoubtedly, some related technologies would still be purchased despite these controls and remain in full compliance with intellectual property rights. However, on the whole, progress will be slowed and other elements of the holistic approach would also constrain advancement. This Indirect Line of Effort provides additional means of shaping and impacting a country's SIF pursuits. Unfortunately, no matter how stringent the controls, it will not deter or halt a committed adversary. It can slow progress and, with effective restrictions on the most advanced mining and construction technologies, potentially limit the sophistication and depth of underground facilities.

The holistic DIME approach affords multiple approaches for slowing progress and denying easy access to technology. The most important aspect will remain the diplomatic approach because it provides the operational framework for all other aspects of containing SIF development. The ultimate arbitrator will always be the military option. Each military option has its own inherently negative factors which may preclude acceptance. However, if the blended DIME approach is adopted as part of U.S. national strategy, there are ways to assert dominance in conjunction with other areas of U.S superiority.

Returning to the primary point, the most important element of the entire SIF concept is the intellectual understanding and recognition of the issue. It must be identified, accepted and embraced as an issue of foremost concern. SIFs are a true source of strategic anxiety. This notion must be inculcated into our national security concepts. Only then, can a multifaceted approach be undertaken to pursue dominance. What are the intellectual drivers of the problem and advanced theories for dominance? The U.S., as a nation, must recognize the problem and attempt to leverage imagination and willpower. It must demonstrate to the world that this is a critical issue not only for the U.S. but for overall global security and stability. The U.S. must ascend to a leadership position on this issue and dominate the global discussion. It is true that since man began to evolve, he sought protection. Caves and shelters were the first passive means of protection. However, as man advanced, fortification emerged and with it came a confrontational notion. Fortification, although passive, became a threat in being. Since that time, it has become a military fundamental to address the of threat fortification. Much of this intellectual understanding was lost in the post-Cold War Era. Nuclear weapons seemed to return as the ultimate deterrent and final arbitrator in any conflict. However, their utility has declined by orders of magnitude. Nuclear weapons cannot be uninvited but the likelihood of use continues to diminish. In parallel with this decline, other technologies have advanced. Without changes to the national effort, fortifications could become the unsolvable military technical problem.

There are two underlying questions which drive the entire SIF issue. First, can man choose to not to fortify? Yes. Will he? No. Therefore, sophisticated efforts must be pursued to counter this fact. There is no other option but to advance the means of

countering this development. Today's fortifications protect the most dangerous and destabilizing elements of rogue nations' pursuits. Weapons of mass destruction and effect are protected by these hardened deep underground facilities. Countries pursue them as both a means of deterrence but also as a tool of power projection. At times, a proactive approach is required. Now is that time. This does not necessarily mean unilateral military strikes but it does require the ability to compel some unwilling nations modify their behavior. Certain tools are required to achieve this affect. Many of these tools are currently unavailable, but must be acquired. The subtexts of the first two questions again present the enduring question; can the U.S. utilize all of its elements of power to counter SIF?

Man as an intellectual species continues to move forward. Knowledge cannot be erased or forced to atrophy. Only through moving intellectually forward, can problems be addressed. There have been times when idealists fail to appreciate this fundamental of man's nature. History has provided many false hopes with arms control and weapons treaties. While these are effective means of delay, the measures have never stopped man's pursuit of more advanced military technology and improved means of military action. This is the final and most compelling reason why the holistic DIME approach must be utilized to counter the increasingly sophisticated and more complex development of underground facilities. If the U.S. does not develop the technology some other nation will and possibly use it against the U.S. or its interests and allies.

Final Conclusions

A new domain has emerged and it must be appreciated for its dynamic effect on policy, strategy and even national resolve. The development of SIF requires a paradigm

shift in the current U.S. strategic and operational approach. Can the U.S. apply all elements of national power (DIME) in a cohesive approach to counter those nations willing to invest in the development of SIF? Yes, it can be done. There are underdeveloped technologies, hard and soft power methods to address the complex requirements and allow for the defeat of these targets on an industrial scale. However, can the U.S. afford to pursue the required solutions? Given current budget constraints and the limits of technology, are there other adequate solutions to addressing the problem without the expense of developing new technologies and capabilities? The answers are uncertain at best. Without a healthy and strong U.S. economy and correspondingly robust defense budgets, the research and development to solve the problems of SIF will not occur. If the technology is currently unobtainable, either due to funding or the natural limits of physics, what are minimum capabilities required to field solutions to the problem set? Without a strategic change of thought, the only interim answer is more penetrators, more delivery platforms and enhanced intelligence, surveillance and reconnaissance. Even this limited set of options requires an understanding which appears absent at the senior levels of leadership and policy. Without even these modest approaches, the U.S. will surrender this new domain to its adversaries. For opponents and rivals, there should no place on or under the earth immune from the destructive reach of the U.S. Failure in this task grants our enemies control of subterranean domain.

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